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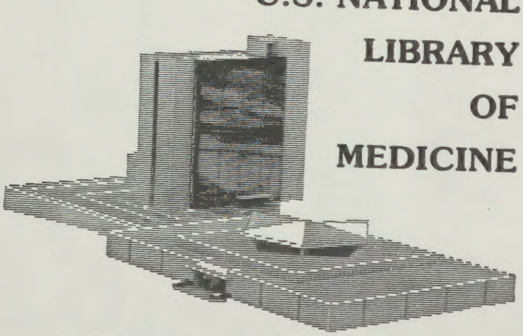

MEDICAL DEPARTMENT

UNITED STATES ARMY

IN WORLD WAR II

NOTE

This volume was written and edited in large part under the direction and supervision of Colonel John Boyd Coates, Jr., M.C., USA, former Director and Editor in Chief, The Historical Unit, U.S. Army Medical Service.

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U. S. Army. Surgeon-General's Office

MEDICAL DEPARTMENT, UNITED STATES ARMY

RADIOLOGY IN WORLD WAR II

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OFFICE OF THE SURGEON GENERAL
DEPARTMENT OF THE ARMY
WASHINGTON, D.C., 1966

RADIOLOGY IN WORLD WAR II

Library of Congress Catalog Card Number: 65-60003

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington, D.C. 20402—Price $8.25

RADIOLOGY IN WORLD WAR II

MEDICAL DEPARTMENT, UNITED STATES ARMY

The volumes comprising the official history of the Medical Department of the U.S. Army in World War II are prepared by The Historical Unit, U.S. Army Medical Service, and published under the direction of The Surgeon General, U.S. Army. These volumes are divided into two series: (1) The administrative or operational series; and (2) the professional, or clinical and technical, series. This is one of the volumes published in the latter series.

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Foreword

In World War II, radiology was an organic part of every hospital, from those far in the rear to those far in the front, and radiology teams were also an organic component of the auxiliary surgical groups that performed front-line surgery. Radiologic service, as the editor of this volume comments rather ruefully in his preface, seems almost to have been taken for granted. It *was* quite generally taken for granted, though the editor cannot properly say, as I can, that the real reason why it often seemed little more than part of the hospital background, so to speak, was the efficiency with which it was usually provided.

On the other hand, provision for radiologic service was not always as simple and effortless as it might seem. Once given the basic equipment without which they could not function at all, radiologists and their technicians kept it operational, often under almost incredible difficulties, and, very frequently, improvised essential accessory equipment also. Behind this near miracle were two other equally remarkable achievements. The first was the production, in adequate quantities, of items of equipment that had sometimes just been devised. The second was the training, as practicing radiologists, of medical officers with little or no formal radiologic training and the creation of competent radiologic technicians out of recently inducted soldiers who, most of them, had never seen an X-ray machine or been in an X-ray darkroom before.

The major radiologic achievement of World War II was the routine diagnostic use of this modality in disease and in combat and noncombat trauma. It also, however, played an important part in many of the medical advances of World War II, notably advances in chest surgery. The development of the concept of the so-called captive lung, for instance, and the revival of decortication in its management would have been impossible without expert radiologic support. The same holds true of removal of foreign bodies from the heart, a procedure in which my own hospital, the 160th General Hospital, made so brilliant a record.

I am pleased to note that in this volume, as in practically all the volumes in this historical series, the editor and the authors are all former medical officers, all of whom saw service in World War II and all of whom write out of their own radiologic knowledge and experience. I am in hearty agreement with the reviewer of a volume of the British World War II medical service history who remarked that the great value of the volume in question was that it was written by a medical officer "who served and is competent to form a reasonable judgment concerning the permanent worth of the work done." Many reviewers and other readers have expressed their approval of the U.S.

Army Medical Department histories for just this reason. There is, naturally, no possible objection to documentation as such, but blind reliance upon it, as Bernard DeVoto, himself a Pulitzer Prize winner in history, once put it, can indeed destroy the spirit that alone giveth life. We have, I think, avoided this fallacy in these historical volumes.

I have always insisted, as have my predecessors in this office, that the story of the Medical Department in World War II shall be told without any attempt at censorship on any level. I am therefore gratified to note that the story of radiology is told with the complete candor and frankness characterizing all preceding volumes of the history. I have lost no opportunity to insist that practical medicomilitary use be made of all of these books and to recommend them to physicians and others in civilian practice. One of my major justifications for this policy is that in them the record of past mistakes is so written that these errors, if properly analyzed and digested, will never occur again. Many of the World War II mistakes would not have occurred if the World War I medical history, which was also written with complete honesty, had been put to practical use.

The editor of this volume, Dr. Kenneth D. A. Allen, has my special thanks because of the circumstances under which he assumed this heavy responsibility after the death of the original editor, Dr. Byrl R. Kirklin, when the work was scarcely begun. The most cursory survey of the book makes clear that this is a job that has been well done. I am also grateful to the authors of the various chapters who answered Dr. Allen's and my Macedonian cries for help and prepared material of so much interest and value.

It was our particular good fortune to secure Dr. Stafford L. Warren as author of the final chapter in this volume, on the role of radiology in the development of the atomic bomb. The health and safety aspects of the entire Manhattan Project and of Operation CROSSROADS in 1946 were his responsibility and, with very few exceptions, the facts are recorded only in his own papers and recollections.

Finally, as in all previous forewords I have prepared in this historical series, I express my grateful appreciation to my associates, particularly the Director and his staff of The Historical Unit, U.S. Army Medical Service, who are performing the prodigious task of preparing and producing these volumes.

LEONARD D. HEATON,
Lieutenant General,
The Surgeon General.

Preface

The use of X-rays in military medicine by the United States began during the Spanish-American War, only 3 years after they were discovered. In his report concerning their use, Capt. William C. Borden, MC, Assistant to The Surgeon General, expatiated on the wartime advantages of this new modality, though the radiographs that illustrate his remarks testify to the crudities of the machines then available, all of which were of the static or coil type, with gas tubes and low power. This technique, Captain Borden emphasized, could be properly used only in base and general hospitals and on hospital ships. It was not suited for what he termed "movable" hospitals, nor did he consider it needed in them. To provide X-ray facilities in the field would, in his opinion, simply furnish an incentive to surgeons to operate on casualties under circumstances in which "adequate asepsis" did not exist. The radiologic experience in subsequent wars was to prove him rather a poor prophet.

When the United States entered World War I, almost 20 years later, the use of X-rays in military medicine was still limited for three fundamental reasons:

1. Radiology as a medical specialty was still in the early stages of development as compared with its status at the beginning of World War II.

2. Equipment and supplies did not lend themselves to the mass use of radiography or the mass production of radiographs of high quality. In fact, the glass plates in use at the beginning of the war and during the major period of U.S. participation in it were sufficient, in themselves, to restrict any very extensive use of diagnostic radiology. It was for entirely practical reasons that fluoroscopy was so widely used in World War I, particularly in the gross evaluation of traumatic problems and the localization of foreign bodies.

3. The number of radiologists was small, for at that time (1917), there were only a few physicians whose practice was limited solely to this specialty. In World War I, most radiologic officers were clinicians who had begun to utilize radiology in civilian practice as a diagnostic adjunct in the limited areas of their special needs.

Between World War I and World War II, tremendous strides were made in the evolution of radiology as a specialty, in the perfection of radiologic equipment, in the development of special techniques and their clinical application, and in the formal training of radiologists.

In other words, at the outbreak of World War II, the X-ray was a well-established diagnostic and therapeutic tool, and radiology was a well-recognized medical specialty. Equipment suitable for military use had received a great deal of study and attention in the preceding decade, and it became avail-

able in time to be useful, though it was procured on what amounted to a crash basis. It is unfortunate that it was not developed earlier.

When the United States entered World War II in December 1941, many radiologists in the Reserve and in the National Guard were already in service. During the war, these radiologists and others who followed them into the Armed Forces helped to develop new clinical concepts. Also, as the potentialities of this specialty and its relation to other specialties became clear, radiologic officers aided materially in the solution of a number of grave clinical problems, such as penetrating injuries of the brain, extensive thoracoabdominal injuries, and—one of the greatest advances ever made in traumatic chest surgery—the elucidation and management of the so-called captive lung after thoracic injuries associated with organizing hemothorax.

In spite of the advances in radiologic training between the World Wars, radiologists were always in short supply during World War II, and radiologic needs could not have been met without the training provided by the courses for medical officers at the Army School of Roentgenology and elsewhere. It is an interesting and heartening commentary on the excellence of these courses and the importance of radiology as a specialty that so many of the officers who received such training remained in this field after the war.

Any mention of radiologic personnel would be incomplete without special commendation of the technicians, the majority of them without any experience in radiology before the war. The training they received at the various schools for technicians, at various hospitals, and, very often, on the job, made possible the quality and quantity of the X-ray service which they rendered. Every radiologic officer would pay tribute to their capability, their industry, and their devotion to their tasks.

The purpose of this volume, like that of every other volume of the history of the U.S. Army Medical Department in World War II, is twofold, (1) to record the events of this war as they concern radiology particularly, and (2) to relate these events so fully and so candidly that the radiologic errors made during it will not be made again. Of these two objectives, the second, negative though it may seem, is perhaps the more important. In World War II, radiology was only one of a number of branches of medicine that proved again the truth of the adage that the lesson of history is never learned.

In World War I, the story of radiology was not told in a separate volume. That it is so told in the history of World War II indicates both its wartime and its postwar place as a major medical specialty. Nonetheless, if even the brief account of radiology in World War I in the official history of that war had been consulted before World War II, a great many wartime lessons could have been derived from it. The supplemental historical notes on radiology in the First World War, prepared by Col. George C. Johnston, MC (they are cited at length in this volume), were not identified and digested until after World War II had ended, when their existence was pointed out by the late Dr. (formerly Lieutenant Colonel, MC) James T. Case, who had served in World War I. Other information concerning radiology in that war

was also in the files of the Office of The Surgeon General, but it was then widely dispersed and poorly indexed, and the medicomilitary generation responsible for the radiologic planning of World War II was not aware of it until too late. The chief reason why so much of the World War I experience was unknown was that almost no effort had been made to publicize the existence of the volumes of the official history.

Certain comparisons between the radiologic events of World War I and World War II make this clear:

1. In World War I, in July 1918, radiology was made a division of the Surgeon General's Office, and the head of the division reported directly to The Surgeon General. In World War II, there was no radiologic consultant in this office until May 1943, and he then served only part time.

Had the World War I precedent been known and followed in World War II, much time and effort would have been spared that were expended in removing radiology from the surgical and other sections under which it was first placed. At the beginning of U.S. participation in World War II, radiology was a subsection in both headquarters and hospitals. It usually operated under surgery. Less often it operated under medicine. Either arrangement was totally illogical, since radiology serves all specialties equally. Radiologic efficiency was greatly increased when, as in ETOUSA (European Theater of Operations, U.S. Army), it was placed under the Chief of Professional Services and when, in hospitals, it was similarly placed under the commanding officer, with the independence of action that it needed.

2. In World War I, a consultant in radiology (first called a division chief) was appointed in the American Expeditionary Forces in 1917, but this fact was not generally known until after World War II had ended.

In that war, however, largely because of the remarkable ability of Brig. Gen. (later Maj. Gen.) Paul R. Hawley, Chief Surgeon, ETOUSA, to predict professional needs, a consultant was promptly appointed in the European theater for every specialty, including radiology. Later, regional consultants were appointed. Full-time consultants in radiology were never appointed for the Mediterranean theater, the China-Burma-India theater, or the Pacific theater. These theaters had only acting consultants who, while they served with great competence, were without the authority and the continuity of action that permanent appointment would have given them. The lack of a full-time consultant in radiology was particularly felt in the Pacific theater which, because of its enormous expanse and its shortages of trained radiologic officers and technicians, had special problems and difficulties. The experience in these theaters, as compared with the experience in the European theater, made it clear that consultants in this specialty should be appointed promptly in all theaters and that they should be assisted by regional consultants wherever, as in the Pacific, the theater is too large for a single consultant to cover it effectively or whenever, as in the European and Pacific theaters, workload is too heavy for him to carry it alone.

3. In World War II, in the European theater, mobile X-ray units mounted on trucks were developed, and the forward radiology that Captain Borden had disparaged in the Spanish-American War thus became a reality. It was not until World War II had ended that it was learned that this important and useful advance was not the "first" it had been supposed to be: In World War I, the French used X-ray units mounted on camions, and the radiologic division chief, Headquarters, American Expeditionary Forces, purchased a number of them for U.S. use. Similar units were devised and tested in the United States and were sent to France although, unfortunately, they were not put into workable condition or properly distributed until after the armistice.

4. A completely portable, hand-carry, knockdown bedside X-ray unit existed before the United States entered World War I, and in spite of its crudities it had much to commend it. A similar piece of equipment was never developed during World War II, and the need for it was keenly felt.

5. Incredible as it may seem, with equipment so precise and so delicate as basic X-ray units, no provision was made in World War II for maintaining and servicing it either in the Zone of Interior or in oversea theaters until hard experience showed the necessity for maintenance and service. Then central depots were established to receive, inspect, and repair broken equipment before it was distributed and to provide maintenance service for it. Precisely the same cycle had occurred in World War I, but the experience was not known, and was therefore not utilized, in the planning for World War II.

6. Schools for the training of both radiologists and X-ray technicians were established in World War II, and their graduates in both categories, as already mentioned, rendered service that was generally excellent and was often superior. A great deal of the trial and error that went into the planning and implementation of these schools in World War II might have been avoided had the similar training experience in World War I been utilized.

7. Ironically, one of the concepts of World War I that did carry over into World War II, from the experience of radiologists who had served in the First World War, was that fluoroscopic localization of foreign bodies would be an essential technique. Elaborate equipment was designed for this purpose in the period just before World War II, but the time, effort, and expense that went into its planning and procurement were practically all wasted. Radiographic localization proved less hazardous and more satisfactory and had the added advantage of providing permanent records.

Therapeutic concepts before World War II included the provision of radiation therapy in the management of infections. This technique proved unnecessary, partly because, with the expert initial wound surgery performed in World War II, infection was never the problem that it had been in World War I and partly because the sulfonamides and penicillin were available and proved capable of controlling the infections that did occur. Gas gangrene was also never a significant problem, and the Kelly technique developed for it was scarcely used after Pearl Harbor.

Radiologists need not be reminded that theirs is a unique specialty. Nonradiologic personnel perhaps need the reminder:

1. Alone among all other specialties, radiology is one in which even the most competent practitioners can render no service at all without a minimum of equipment. Certain accessory equipment can be improvised, and U.S. ingenuity never showed to better advantage than in the improvisations created in World War II. But basic equipment cannot be improvised. It must be provided.

2. The provision of X-ray equipment in World War II was no simple matter. Every single piece of it was constructed of critical materials, for which there were dozens of other priority demands. X-ray equipment is bulky and space occupying, and it had to compete for transportation with other essential equipment that occupied much less space. Also, in spite of its bulk, X-ray equipment is exceedingly delicate, and it therefore had to be handled with great care. Breakage, when equipment was not so handled, was a serious problem.

3. X-ray equipment requires specialized technical personnel to operate it, and specially trained professional personnel to make its products—that is, radiographs—useful by interpretation. Radiographs of good quality were hard to produce in the circumstances that often prevailed in oversea theaters, with vagaries of current, inadequate water supply, and other shortages and difficulties to contend with.

4. Replacement of parts of basic equipment was another major problem. When, for instance, a cable or a tube blew out and replacement was necessary through normal channels in World War II, a badly needed X-ray machine was often rendered useless for many weeks. Even in the Zone of Interior it sometimes took from 3 to 6 weeks to replace a cable or a tube. Hospital report after hospital report carried the urgent recommendation that extra tubes and cables be supplied with all units, to provide against emergencies, and that supply depots keep these items in stock in generous numbers, particularly in areas in which resupply was likely to be difficult.

5. Finally, and again uniquely, X-ray equipment is hazardous to use, and protective measures require special materials.

In retrospect, radiologists, like many others, were slow to appreciate the imminence of World War II, in spite of the march of events that should have carried their own warnings. In September 1939, the President declared a Limited National Emergency and authorized the Army to recruit to its full statutory strength. In August 1940, the National Guard and Reserve Corps were called to active service. The following month the Selective Service Act was passed, and the authorized strength of the Army was increased from 242,000 to 1,400,000 men. In August 1941, Selective Service was extended and the President was authorized to recall retired Regular Army personnel to active duty. The official M-day that had been planned for was never formally invoked, but Pearl Harbor, on 7 December 1941, left no doubt that it had, in substance, been reached and passed.

The Radiological Society of North America met in the Fairmont Hotel in San Francisco, Calif., 1–5 December 1941. The program, of course, had been made up months in advance, but at this distance in time, in view of the events just listed, it seems entirely unrealistic that not a single item on it concerned medicomilitary matters or the relation of radiology to military medicine. There was soon to be a dramatic awakening for three of the Society members who traveled together from the West Coast to Denver, Colo., Dr. James Kelly of Omaha, Nebr., particularly known for his work on radiation therapy in nonneoplastic diseases; Dr. Warren W. Fury of Chicago, Ill., who had played an important role in the development of the American College of Radiology and the Section on Radiology of the American Medical Association; and the undersigned (Dr. Kenneth D. A. Allen of Denver).

Dr. Kelly and Dr. Fury were to be Dr. Allen's luncheon guests at the Denver Country Club, Sunday, 7 December 1941, during their stopover in Denver between trains. As the three physicians entered the Club, at 1 o'clock, mountain time, the doorman called out to them, "The Japs are bombing Pearl Harbor!"

On the trip from the coast to Denver there had been some conversation about the war in Europe, but it had been almost casual, and without personal application. Now everything was changed. The luncheon at the Club was hurried and somber, and the talk concerned only the war and its national and personal effects. All three radiologists knew that the events of that day marked a turn in the national road and that no lives would ever be the same again.

For Dr. Kelly and Dr. Fury, the war was to mean a continuation of civilian practice, with all the modifications, perplexities, and added responsibilities imposed by wartime circumstances. For Dr. Allen, the war was to mean a long, busy, stimulating 4 years, beginning with duty as instructor at the Enlisted Technicians School, Fitzsimons General Hospital, Denver, Colo., continuing with the duties of Senior Consultant in Radiology, in the European theater. Finally—long after the war—came the responsibility of editing the history of radiology in World War II.

Enough has been said about failure to utilize the World War I experience in World War II to make clear why there should be an official medical history of every war; why there is a historical note dealing with the experience of previous wars in this volume and in many other volumes of the medical history of World War II; and why every effort should be made, as the present Surgeon General has particularly directed, to make known the existence of this history and to see to it that its contents are read, digested, and applied. Much time, many tribulations, and an incalculable waste of effort and money would have been saved in World War II if the lessons of World War I had been utilized. Radiology, as already pointed out, was not the only specialty in which these lessons had to be learned over again.

The preparation of the history of radiology in World War II from 13 to 17 years after the event has had both advantages and disadvantages. One's

outlook becomes more objective with the passage of time, but on the other hand the image is sometimes blurred by presbyopic vision. This history, of course, should have been prepared earlier, but for many reasons, it could not be. Be this as it may, when the editor and associate editors of this volume, as well as the contributors to it, assumed the responsibility for it, they were confronted with a fact, not with a theory, and had to proceed accordingly.

It is hoped that those who read this volume will bear in mind that it is basically a chronicle of events prepared chiefly by those who participated in them. It is not historiography. The source material was extremely limited, being chiefly official hospital reports, in most of which the radiologic record was perfunctory and uninformative, apparently because radiology was a service that was taken for granted. Statistical data were singularly lacking. It would be interesting to know the total volume of X-ray work in relation to total hospital admissions and outpatient dispensary visits, but these data do not exist, and the best that could be done was to use occasional reports of individual hospitals in the belief—probably correct—that they were typical of the total experience.

The hospital records and all other sources used in this volume are on file in the General Reference and Research Branch, The Historical Unit, U.S. Army Medical Service, Washington, D.C., where they can be consulted by those who are interested in such details as exist. The hospital records are, as a rule, clearly identified in the text and the information is therefore not repeated formally in the reference lists appended to each chapter.

Many reports of special techniques and many clinical observations were published in the literature during and immediately after the war. They have been used freely.

In spite of these sources, it would have been impossible to prepare this volume without the generous assistance of the many radiologists who served in World War II and who took the time, after a long lapse of years, from their busy peacetime practices to search out their personal records and write out their recollections of their Army radiologic service. All of them contributed to the composite story of radiology in World War II, and special acknowledgment of their invaluable assistance is made elsewhere.

The authors of, and the contributors to, the various chapters in this volume are all of them, it should be emphasized again, radiologists who served actively, in one capacity or another, in World War II. The former Editor-in-Chief of the official history of the U.S. Army Medical Department in World War II, Col. John Boyd Coates, Jr., MC, and his successor, Col. Arnold Lorentz Ahnfeldt, MC, took the position, with the warm support of The Surgeon General, that the medical officers who served in the war are the persons best qualified to write about what happened medically during it. Their accounts were, on the whole, remarkably objective, and in substance they have been little changed.

The chapters on training and equipment, prepared by Col. Alfred A. de Lorimier, MC, were essentially complete when he died. He worked from his

own notes, and his endeavors on this history during the last months of his life represent his final service to his country and to the specialty to which he was so devoted.

The chapter on consultant service in the Zone of Interior, to be prepared by Dr. Byrl R. Kirklin, who served during part of the war as Consultant in Radiology, Office of The Surgeon General, had barely been started at the time of his death. His method of operating, with his files chiefly in his head, has resulted in gaps and discrepancies that cannot now be corrected. Dr. Kirklin was Secretary of the American Board of Radiology when the United States entered World War II, and his position gave him a wide knowledge of radiologists and their training and ability that enabled him to render invaluable service in the assignment of personnel.

After much deliberation, it was decided that the only practical way to prepare this history of radiology in World War II was by theaters. No other scheme seemed workable. This method, however, inevitably has resulted in a certain amount of repetition. It is hoped that those who read this volume will bear in mind that such repetition was impossible to avoid if the story of each theater was to be told in full. It does not represent careless writing. War itself is both repetitious and monotonous.

It is regrettable that more illustrations were not available to demonstrate the clinical entities, especially the tropical diseases, studied radiographically during the war. The films were often of very poor quality to begin with, because of the circumstances under which they were made, and most of them simply did not lend themselves to reproduction.

World War III, if it is to occur, will not necessarily be a nuclear war. The effort to ban nuclear weapons, with their power to destroy the whole world, still continues. The final chapter in this volume makes clear why it must continue. Gas was used in World War I but was banned in World War II. It may be, should a third World War come to pass, that nuclear weapons will be similarly banned in it. Meantime, radiologic service must be provided for the brush-fire wars that have occurred, and are likely to continue to occur, all over the world.

Details of radiologic technique may change in the future, but from one combat experience to another fundamentals of radiology are unlikely to change. For this and many other reasons, the time and effort spent in the preparation of this history of radiology in World War II must be considered well spent. The volume has been prepared for exactly the reason that Andrew Smith, Director General, British Army Medical Service, prepared the medical history of the Crimean War, which was the first formal medicomilitary history. He had suffered, he wrote, "in the absence of all details calculated to instruct," and he was determined that the "doubts and indescribable perplexities" that had been his lot should not be the lot of those who came after him.

That has been the aim of those of us who served as radiologists in World War II and who have prepared this history of radiology in it.

KENNETH D. A. ALLEN, M.D.

Acknowledgments

The late Dr. Byrl R. Kirklin, who served as Consultant in Radiology, Office of The Surgeon General, in World War II, was selected as the editor of the history of this specialty in that war. The selection was admirable, but his work was barely started when he died.

When I was asked to take Dr. Kirklin's place, I realized at once that this was a task I could not possibly undertake without the cooperation and assistance of my radiologic confrères. Only when I was assured of their help did I consent to assume the responsibility. Now that the history of radiology in World War II is completed, I realize, far more than I did when the book was no more than a conception, how essential that help was and how much I owe to them for it.

It is a pleasant necessity to express my thanks to the radiologists who helped me in this task, as well as to others not of the radiologic profession who assisted me in various ways. I am including by name only those who made significant contributions that helped the authors in the preparation of their material. It would be impossible to list all of those who helped us in other ways—by letters, by accounts of experiences that became part of a composite picture, by the key to a missing fact, or by the location of a missing source. I hope that all of those included in these latter categories will realize how grateful I am to them for these items which, though small individually, amounted to a great deal in the aggregate.

Specifically, my thanks are due to the following persons and organizations:

The total membership of the Advisory Editorial Board for Radiology participated in the planning and general organization of this volume. They all brought enthusiasm as well as knowledge to the task, and full advantage was taken of both. The late Col. Alfred A. de Lorimier, MC, USA, who prepared the basic material for the chapters on equipment and on personnel and training, was a member of this Board and rendered great service on it in addition to his work as author of these two important chapters.

The late Col. John A. Isherwood, MC, USA, reviewed and corrected these chapters as well as all other chapters dealing with Zone of Interior concerns.

Maxwell Dauer, Ph. D. (Lieutenant Colonel, MSC, USA (Ret.)), the last Commandant of the Army School of Roentgenology, also reviewed the chapters prepared by Colonel de Lorimier. No one was better qualified than he for this assignment.

These chapters were also reviewed by Col. Paul A. Paden, MC, USA. Colonel Paden provided much of the information for the chapter dealing with

Dr. Kirklin's activities as Consultant in Radiology, Office of The Surgeon General.

Information concerning radiology in World War I, much of it not published in the official history of that war, was provided by two radiologists who had served in it, Dr. Fred O. Coe and the late Dr. James T. Case.

Dr. Earl R. Crowder, who served as Acting Consultant in Radiology in the Mediterranean theater in World War II, reviewed the chapter on that theater and made many helpful suggestions concerning it. Former Sgt. Clark R. Warren also furnished much assistance in the preparation of this chapter, particularly in the collection and provision of illustrations for it.

Material of various sorts was contributed, often at the expenditure of considerable time and trouble, from their private papers and their recollections by Dr. Charles L. Baird, Dr. Robert P. Ball, Dr. Cesare Gianturco, Dr. Norman Heilbrun, Dr. Arthur H. Joistad, Jr., and Dr. Magnus I. Smedal.

My particular thanks are due to Dr. Charles W. Reavis, who served as editor for the section on the Pacific Ocean areas and who wrote many of the chapters in it himself. Almost no formal material existed for radiology in these areas, and Dr. Reavis was obliged to seek the data out from individual radiologists who had served in them. As noted elsewhere, it was impossible, because of the overlapping nature of much of this material, to use individual experiences as such, and they had to be incorporated in composite accounts. Special thanks are due to the following radiologists, some of whom also served as authors of chapters or parts of chapters, for the contributions just described:

Dr. Vernon L. Bolton	Dr. Ernest B. Newman
Dr. William C. Coles	Dr. Sidney Rubenfeld
Dr. Donald B. Fletcher	Dr. Walter J. Stork
Dr. Horace D. Gray	Dr. Frederick W. Van Buskirk
Dr. Ralph L. Moore	Dr. Harold A. Vinson
Dr. Joseph L. Morton	Dr. Egon G. Wissing

Photographs for various sections of this book were supplied by Dr. Gerald S. Maresh, Dr. C. Philip Naidorf, and Dr. Dan Tucker. Col. Henry C. Harrell, MC, USA, Director, Division of Radiology, Walter Reed General Hospital, Washington, D.C., assisted in the identification of several dozen unidentified illustrations, eliminating those not useful for our purposes. He also provided, from the division teaching collection, many of the illustrations of tropical diseases encountered in the Pacific Ocean areas and the Middle East during World War II.

Appreciation is expressed to the Picker X-Ray Corp., The Westinghouse Electric Corp., and Paul B. Hoeber, Inc., for permission to reproduce illustrations from copyright and other material.

Mrs. M. Imogene Andrews made the final copy of this manuscript with great competence and skill. She met deadlines at considerable personal inconvenience when the manuscript was being completed. She was also of great

assistance to the Associate Editor, Miss Elizabeth M. McFetridge, when the latter was preparing the index.

There are many branches and persons to thank in The Historical Unit, U.S. Army Medical Service, which has the mission of preparing and publishing the volumes of the history of the Medical Department in World War II under the direction of The Surgeon General.

My profound thanks are due to Col. John Boyd Coates, Jr., MC, USA, former Director, The Historical Unit, USAMEDS, and Editor-in-Chief of the history of the U.S. Army Medical Department in World War II. He conceived the volume, did the original planning, and, by using the Churchillian technique (a combination of the carrot and the stick) on delinquent authors and editors, he brought the book to its conclusion. No editor could ask for warmer cooperation than I have received from him.

Colonel Coates' successor, Col. Arnold Lorentz Ahnfeldt, MC, who became Director and Editor-in-Chief of The Historical Unit on 10 September 1964, has been extremely cooperative in the final stages of editing of this volume. This is greatly appreciated.

The original administrative work on this book was done by Col. Charles A. Pendlyshok, MSC. The responsibility was then assumed by Maj. Albert C. Riggs, MSC. Major Riggs was separated from service in September 1962, and we were extremely fortunate in that he maintained his interest in the work, and assisted us with it as called upon, ever since. After Colonel de Lorimier's death, Major Riggs took over his mass of basic material and reduced it to usable size before turning it over to others for rewriting.

Charles M. Wiltse, Ph. D., Chief, Historians Branch, read and corrected the background historical sections.

Mrs. Josephine P. Kyle, formerly Chief, General Reference and Research Branch, began the research work for this volume. The work was continued by her successors, first Major Riggs and then Mr. Roderick M. Engert. Special thanks are due Mrs. Esther E. Rohlader, Assistant Chief of the Branch, who had the radiology volume as one of her special assignments after Mrs. Kyle's retirement. Mrs. Rohlader answered questions, dug up material, located information on elusive former medical officers, and rose to every need with remarkable promptness and accuracy.

Maps were prepared by Miss Elizabeth P. Mason, Chief, Cartographic Section, and Miss Jean A. Saffran, Cartographic Draftsman, of the Special Projects Branch, The Historical Unit.

The Editorial Branch deserves great credit for its careful and expeditious work in preparing the volume for the printer. Mrs. Pauline B. Vivette, who was assigned as principal editor for the volume, performed the editorial work with the assistance of Miss Rebecca L. Duberstein, Miss C. Louise Brady, Mrs. Elaine R. Stevenson, Mrs. Marjorie G. Shears, and Mrs. Martha R. Stephens, all editors. Mrs. Stephens edited the layouts and the artwork.

My deep appreciation is expressed to Mrs. Mindell W. Stein for indefatigable work in collecting and sorting valuable material from numerous radiolo-

gists, many of whom she worked with during her own vacation time. If it had not been for her willingness to assist me and her enthusiastic cooperation, I could not have undertaken to edit this volume.

Finally, to Miss Elizabeth M. McFetridge I express my admiration and my warm appreciation for the editorial assistance she has given to the authors of the various chapters of this book and to me. Her keen and unusual abilities were of inestimable help in the preparation of the final manuscript, including the index.

KENNETH D. A. ALLEN, M.D.

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Part I

MILITARY ROENTGENOLOGY BEFORE WORLD WAR II

CHAPTER I

Historical Note

Kenneth D. A. Allen, M.D.

MILITARY ROENTGENOLOGY BEFORE WORLD WAR I [1]

Ethiopian Campaign, 1896.—In May 1896, just 6 months after Roentgen had announced his epochal discovery, the first military radiographs were made at the Military Hospital in Naples, at the end of Italy's disastrous campaign in Ethiopia. By this time, Roentgen's primitive apparatus had already been modified and improved, and the two cases, both injuries of the forearm, in which the new modality was used proved its value: Previous attempts to remove the retained bullets had been unsuccessful; after their X-ray localization, both were readily removed. Lt. Col. Giuseppe Alvaro, who made the examinations, predicted that this new method would also be useful in diagnosing bone disease, determining the forms of fractures, and studying skeletal deformities and the formation of internal concretions. His remarks were to prove prophetic.

Greco-Turkish War, 1897.—The first use of military roentgenology, as such, was, as just indicated, in a hospital well to the rear. A year later, in the Greco-Turkish War of 1897, this new modality was used in hospitals much nearer the front. Küttner, who used it in a hospital in Constantinople, provided by the Central Committee of the German Red Cross, found it very helpful in establishing the presence or absence of foreign bodies and their position and in facilitating their removal, in osteomyelitis and draining wounds, and in injuries to the nervous system (especially those associated with severe paralysis). He concluded, however, that, with the bulky type of machine then necessary, this method would not be useful in the current equivalent of modern field or evacuation hospitals.

Medical officers who operated the two hospitals set up in Greece by the British Red Cross arrived at much the same conclusions. In addition to the mechanical difficulties connected with the weight of the apparatus, the fragility of the tubes and the plates, and the unreliability of the current, they were handicapped by the superstition of the natives, who "* * * looked on the

[1] Unless otherwise indicated, the material in this chapter dealing with the use of X-ray before World War I is summarized from the excellent, well-documented Caldwell-Carman Lecture delivered by Dr. Lawrence Reynolds in September 1944 before the joint meeting of the American Roentgen Ray Society and the Radiological Society of North America (*1*).

whole affair as the work of the Devil which made it difficult to take a skiagram when the subject was constantly crossing himself unless strictly watched."

British medical officers also feared that the use of X-ray at the front might be an incentive to surgeons to operate prematurely in bad surroundings, a fear later expressed by U.S. radiologists (p. 4).

Tirah Campaign, 1896.—The Tirah Campaign was precipitated by the uprising of native tribes and the necessity for safeguarding British access to India from Afghanistan by way of the Khyber Pass. No white men, and no troops other than native troops, had set foot on the high-lying Tirah Plateau until General Sir William Lockhart brought his armies into the region in October 1897, supported by 23 field hospitals. The X-ray facilities provided —and used for the first time on the actual field of battle—were brought out, entirely at his own expense, and operated by Surg. Maj. W. C. Beevor (*2*). Major Beevor found roentgenographs of the greatest value in locating bullets and lead splinters, and he made many important practical observations:

1. X-ray apparatus for military work should be "get-at-able," so that the inevitable defects of wear and tear could be promptly remedied.
2. Every portion of the apparatus (coils, condensers, connections, etc.) should be packed in cases that could be opened and inspected at a moment's notice, without special instruments.
3. The X-ray operator should be "independent of help."

Major Beevor had only three tubes, which he used more than 200 times, but at the end of the campaign they were in as good working order as when they were taken out. Transport of equipment, however, was a major problem; after trying all kinds, including mules, camels, and wheeled vehicles, he found human transportation the most efficient. An even greater problem was the generation of electricity. The heavy, cumbersome primary battery, worked by a mixture of bichromate of potash and sulfuric acid, was too dangerous for military transport unless a special courier went along to look after the acid. Major Beevor condemned this method for field use and recommended the employment of a hand dynamo and portable accumulator. Glass plates proved exceedingly satisfactory. As in earlier experiences, the fluorescent screen, the surface of which was protected with a layer of celanite, seemed the most important part of the apparatus.

From his experience in the Tirah Campaign, Major Beevor concluded "* * * it is now the duty of every civilized nation to supply its wounded in war with an X-ray apparatus, amongst other surgical aids, not only at base hospitals, but close at hand, wherever they may be fighting and exposing themselves to injury in the performance of their hazardous duty."

River War, 1896–98.—The war of the Soudan, generally known as the River War, was fought between 1896 and 1898, to put down the tribes in the Soudan, by British and Egyptian military units under Lord Kitchener. After numerous engagements had been fought as the invading troops pursued

the natives up the Nile, the Dervishes were crushingly defeated at Omdurman, "in the most signal triumph ever gained by the arms of science over barbarians."

Among the "arms of science" was a roentgen ray apparatus, in charge of Maj. J. Battersby (*3*). It consisted of two 10-inch and one 6-inch coils, which, with other necessary electrical instruments, were enclosed in a strong oak box. The apparatus was too heavy for transport by camel or mule, and a device of ropes and poles was rigged up so that it could be carried on the shoulders of four men. Additional apparatus consisted of a storage battery with separate cells; if a cell was injured or a plate buckled, a spare could be substituted.

Major Battersby also brought with him four 10-inch ordinary bianodic focus tubes, which he personally tested before he left with the troops. Two of these tubes did excellent work, one being better for screenwork and the other for roentgenography. The fluorescent screen was most useful at night but unsatisfactory during the day because no darkroom was available and the intense sunlight penetrated the thickest wood. The surface of the screen was protected by a layer of celluloid, a matter of great importance in the warm and dusty climate. Only glass plates gave satisfactory results.

The temperature varied from 100° to 122° F. in the shade, and at one time the apparatus had to travel for 2 days and a night in an open truck, exposed during the day to the fierce heat of a blazing sun. Before he left Cairo, Major Battersby had had very thick felt covers made to surround the outer boxes containing the coils and storage batteries. By keeping the felt wet—it required wetting every 2 hours—the apparatus arrived at its destination without damage.

Generation of the primary electrical current for charging the storage batteries or working the coils directly was accomplished by the use of a small, easily transportable dynamo driven by a tandem bicycle.

Of the 175 British casualties at the Battle of Omdurman, 121 were brought to the surgical hospital at Abadieh. In bullet wounds of the extremities, anteroposterior and lateral views provided satisfactory localizing data. In the deeper structures, the best results were obtained by a modification of the Mackenzie-Davidson localizing apparatus. In 20 of 21 cases in which the presence or absence of a bullet could not be determined by ordinary methods, an accurate diagnosis was arrived at by roentgenologic techniques.

Boer War, 1899.—When the Boer War began, the War of the Soudan had ended, and the medical units there, with the X-ray equipment which had been used in them, were ordered to South Africa. Here, at the Siege of Ladysmith, roentgenography was carried out under shellfire for a considerable period (*4*). Lt. F. Bruce, who was in charge of roentgenology, had not considered the provision of current in the Soudan by means of the dynamo-bicycle arrangement entirely satisfactory. He therefore had the batteries of the X-ray apparatus charged before he left Cairo, and when he reached his

destination, he was able to arrange with a flour mill in the vicinity to have the dynamo he had brought along driven from the mill shafting. The arrangement was extremely efficient.

Roentgenographs were made on about half the casualties, and large numbers were also examined by fluoroscopy. The techniques employed were of great clinical value in respect to the localization of bullets and the demonstration of fractures. Some modifications of the usual methods were necessary because of the patients' movements when shells were heard in the immediate vicinity; exposures were made as short as possible, lasting from 10 to 15 minutes instead of the usual 20 to 30 minutes, with correspondingly long developments.

By the time of the Boer War, the usefulness of X-rays in military practice had become so evident that all general hospitals were provided with equipment and many smaller hospitals were similarly equipped.

Spanish-American War, 1898.—Roentgenology had only a limited use in the Spanish-American War, partly because of the type of warfare and partly because typhoid fever, rather than battle wounds, occupied the attention of the Medical Corps (*5*). The more important of the general hospitals were supplied with the type of equipment used in earlier wars; that is, coil apparatus and storage batteries. Three hospital ships were similarly equipped. The recently constructed static apparatus was so heavy that its use was confined to fixed hospitals and hospital ships. Capt. (later Maj.) William C. Borden, MC, who recorded the experience, did not believe it would be wise to place X-ray apparatus any farther forward, on the ground that provision of these facilities would encourage surgeons to try to remove bullets under less than optimum conditions.

ROENTGENOLOGY IN WORLD WAR I [2]

Administrative Considerations

In April 1917, when the United States entered World War I, only the larger of the military hospitals were equipped with X-ray apparatus. No effort had been made to maintain a selected group of officers who specialized in roentgenology. It was uncommon, in fact, to have any medical officer, even in the largest hospitals, devote his full time to radiology, which was usually assigned as an additional duty. A certain amount of theoretical and practical instruction in radiology was included in the curriculum of the Army Medical School, Washington, D.C., but it was intended primarily as a "broadening educational feature rather than * * * creation of specialists." Supply and equipment of X-ray departments were handled as part of finances and supply in general.

[2] The material dealing with World War I, unless otherwise indicated, is derived from the official history of that war (*6–9*) and from reports by Col. Arthur C. Christie, MC, and Col. George C. Johnston, MC (*10, 11*). Helpful information was also furnished by Dr. Fred O. Coe (*12*) and Dr. James T. Case (*13*).

Specialization in radiology was thus fortuitous, dependent almost entirely on the initiative and interest displayed by individual officers. As a result, there was only one radiologist in the Army in April 1917, Col. Philip Huntington, MC, and he was almost immediately placed in an administrative position (*12*), not connected with radiology.

The first radiologists assigned to the Surgeon General's Office in World War I were in the Supply Division. When a Division of Roentgenology was created in that office on 10 July 1918, a former medical officer who had specialized in this field, Maj. (later Col.) Arthur C. Christie, MC, was called back into service to head it (*10*). When he was ordered overseas in September 1918, to take charge of all X-ray work on the Western Front, Lt. Col. (later Col.) George C. Johnston, MC, was his replacement.

The Division of Roentgenology in the Surgeon General's Office was established on the recommendation of the officer in charge of the Supply Division in that office, who had recognized from the beginning the peculiar problems of roentgenologic supply and had handled it as a separate function in his office. When the special Division of Roentgenology was established, arrangements were made for the officers assigned to it to maintain close liaison with the Supply Division, to expedite procurement of equipment. When all procurement was consolidated under the War Production Board in 1918, the privilege of purchasing X-ray equipment was left with the Supply Division of the Surgeon General's Office after its highly specialized character was pointed out.

Roentgenology continued as a separate division in the Surgeon General's Office throughout the war and until 1 December 1918, when it became the Section of Roentgenology under the Division of Surgery. Close liaison, however, was still maintained with the Finance and Supply Division (then operating under the Purchase, Storage, and Traffic Division), apparently on a personal basis. The result of these contacts was that X-ray material was received much sooner than the 30 to 90 days usually required when requests went through channels (*10*).

Procurement and Supply

At the beginning of World War I, X-ray equipment consisted of stationary apparatus at general hospitals and larger post hospitals and a few portable sets with motor generators and high-tension transformers. This equipment had served satisfactorily on the Mexican border and at Veracruz but was too cumbersome and unreliable for general military use.

On 15 April 1917, at the invitation of the Council of National Defense, a number of leading physicians, surgeons, chemists, and instrument makers met in Washington, with the idea of standardizing drugs, equipment, and other items for military use (*10*). Dr. George C. Johnston served as chairman of a committee on X-ray equipment, on which Dr. Arthur C. Christie

also served. Prof. Arthur W. Goodspeed, of the University of Pennsylvania, was appointed to the committee but withdrew because of the highly practical nature of its functions and his own academic interests.

This committee prepared specifications covering all types of X-ray apparatus, making them broad enough to permit the use of the output of all manufacturers. The members of the committee realized that a great quantity of apparatus would be required, more than any single manufacturer could possibly produce. They also realized that there had not yet been sufficient experience in military roentgenology to justify specifying any single type of equipment to the exclusion of other types.

After conferences with the Committee on Preparedness of the American Roentgen Ray Society (p. 19) and other experienced radiologists, it was decided to ask all manufacturers to submit samples of transformers for investigation and testing. Few radiologists were familiar enough with all types of equipment to warrant individual evaluations, and group investigation and comparison seemed the fairest plan. It would have been ideal to select a single type of equipment for general manufacture, with interchangeable parts; but the need was immediate, and no delay in production could be permitted.

The investigation was carried out at the Cornell Medical College. Some manufacturers, misunderstanding the purpose of the inspection, which they regarded as a competitive test, did not submit samples. All five samples which were submitted were approved, some with minor alterations for military reasons, after the plants in question had been inspected by Major Christie, to secure information concerning their capacities.

Planning was on the basis of X-ray laboratories suitable for 500-bed base hospitals in camps to house 10,000 troops each, on the basis of an Army of half a million men (*10*). As the size of the Army increased—it reached 3,634,000 at the end of the war—the size of the base hospitals was successively increased. In some instances, the original 500 beds became several thousand, and the overload was often 300 to 400 percent. The original planning, however, had been soundly done and required practically no basic changes in spite of the enormous expansion that occurred. Similarly, few changes, except numerically, were necessary in the X-ray supply tables prepared by the committee and adopted by the Hospital Division, the Surgeon General's Office, on the recommendation of the Council of National Defense in 1917.

The supply of X-ray equipment to hospitals in camps and cantonments proceeded rapidly, and the aim of the Division of Roentgenology, to have complete X-ray equipment installed, in operation, and in charge of competent radiologists, by the opening date of each installation, was generally achieved.

Production of radiologic equipment had reached full capacity when the armistice was signed on 11 November 1918. Whenever practical, contracts were terminated without waiting for formal authorization; and many thousands of dollars were thus saved (*10*).

Oversea supply.—When the first contingent of the American Expeditionary Forces went to France, several shipments of equipment were diverted

from the Medical Supply Depot in Washington and sent overseas. Two shipments arrived in good condition, were ultimately installed in base hospitals, and gave good service in them throughout the war. The first U.S. hospitals which went to France served with the British Expeditionary Force, and Base Hospital No. 18, the Johns Hopkins Hospital Unit, was the first to begin work with U.S. equipment in November 1917 (*14*). 1st Lt. Charles A. Waters, MC, used the old Gaiffe coil and mercury interrupter left at the French hospital in Bazoilles which this unit occupied. Current was supplied by an electrogenic set of such small capacity and located so far from the X-ray machine that he was happy when he secured 1 ma. (milliampere) of current through his tube. This hospital later received one of the machines just mentioned, which arrived in good condition.

Most of the hospitals which arrived in the theater in the first months of U.S. participation in the war secured localizing devices, hand fluoroscopes and similar equipment, and plates from French sources. They took over other apparatus in French hospitals in which they worked. The basic French equipment was rather primitive to American eyes; it consisted of 8- or 10-inch coils; mercury interrupters; wooden tables with, to Americans, a startling lack of protection; and, at the most, 2–3 ma. of current and a usable spark gap.

It continued to be necessary to purchase large quantities of French equipment, which was decidedly inferior to American equipment, until well into 1918. By the time the armistice was signed, however, there had been shipped to oversea installations 150 complete sets of equipment for base hospitals, 264 portable machines, 250 bedside machines, 55 X-ray ambulances, and hundreds of accessory items.[3] Shipments were often delayed because the tonnage and bulk of X-ray equipment gave it a low priority in comparison with other military material. Also, in the winter of 1917–18, there were often considerable accumulations of freight because of the unprecedented cold.

Distribution overseas, however, was by no means as good as it should have been. French sources, as noted, often had to be used for that reason. In October 1918, for instance, it was learned that none of the X-ray ambulances shipped over during the previous months had been placed in action (p. 51). They had remained in one area for so long, in fact, that they had sunk into the ground and had to be moved by caterpillar tractors. On a number of occasions, requests for additional equipment, such as X-ray tables and bedside units, were not honored in the United States because of the realization that poor distribution overseas rather than lack of supplies had inspired them.

Breakage and Repair

The mortality of Coolidge tubes was initially high, partly because of attempts to pass very heavy currents through them and partly because of

[3] In August 1918, the Siberian Expeditionary Forces were equipped with X-ray apparatus and other supplies estimated to last for a year (*10*).

breakage. When these tubes were shipped overseas in carefully constructed packing cases, with spring-supported interior cages, about half were broken. When they were shipped in very light, open-type birdcage crates, 409 of the first 490 shipped arrived undamaged, and there was no breakage at all in the next 400 tubes shipped in this manner. Special handling was necessary. The crates were hand-carried aboard ship (last of all cargo), were carefully packed with mattresses and other dunnage, and were hand-carried off the ship first of all cargo.

Instructions, which were not always followed, were issued that all apparatus received overseas must be inspected at the Supply Depot before distribution, to detect and correct breakages.

In March 1918, on the recommendation of Maj. Preston M. Hickey, MC, who had relieved Major Christie when the latter was recalled to the United States in February 1918, an X-ray section was set up in the Medical Department Repair Shop in Europe, and a number of Sanitary Corps officers (technicians) were trained to service and repair equipment. Later that year (1918), similarly trained Sanitary Corps officers were assigned to various medical supply depots throughout the United States, to be available for repairs and also to supervise the installation of equipment.

After the armistice, when camps and hospitals began to be closed, a great deal of X-ray equipment was received in the New York Medical Supply Depot in badly damaged condition because of improper packing. The difficulty ended when orders were issued that all equipment must be packed under the supervision of an experienced radiologist, who would certify that it had been correctly packed. In May 1919, it was recommended that a repair shop be established at the New York Medical Supply Depot, for the repair, salvage, and testing of all returned equipment before it was reissued or placed in storage.

During the war, testing of apparatus and other items offered to the Roentgenology Division, Surgeon General's Office, was carried out in a variety of places until August 1918, when it was concentrated in space provided at the Army Medical School.

X-Ray Manual

In 1917, plans were made for the preparation and publication of a small X-ray manual, with Maj. William F. Manges, MC, as editor and with contributions by a number of medical officers and civilian radiologists (*15*). The material concerned chiefly electrophysics, localization techniques, and descriptions of the special apparatus employed by the U.S. Army. The second edition of the manual, prepared and published in 1919, contained all of the material in the first edition, supplemented by an extensive and comprehensive section on X-ray diagnosis.

Hospital Inspections

In November 1918, formal inspections of X-ray laboratories in hospitals in the Zone of Interior were set up by the Surgeon General's Office (*16*). The "Circular of Information for Supervising Inspectors of X-ray Laboratories, Concerning the Method of Preparing Inspection Forms" required data on buildings and floor space (space, ventilation, lighting, heating, power supply, neatness, recommendations); apparatus and supplies; general care of apparatus; personnel; volume and quality of work; and administration.

These inspections (*10*) revealed that "taken as a whole and on the average" the departments investigated "had little or nothing to be ashamed of" and were "delivering the goods as it were." On the other hand, the summarized reports continued:

> None of the departments were working up to full capacity, although a few thought they were. During the influenza, as far as could be ascertained, departments made good, doing all, and more than, they were called upon to do. There was a decided lack of conferences with other departments. Reports sent out could be so sent at an earlier date with better regime. The clinical history was not made use of. No cross-indexing was observed. There is a need of trained enlisted personnel to do the work in small departments. There was a decided lack of cleanliness. More 5 x 7 plates and films could be used. There was some overstock noticed especially in tubes. There was a lack of administrative qualifications. Form 55 L is not properly filled out in most instances.

Detailed reports of inspections expanded on these various points and made recommendations for correction and improvement.

It was also noted that it was a pity, in view of the great amount of valuable material available, that more articles had not been prepared for publication. Part of the explanation was considered to be preoccupation with professional duties, but inertia was stated to be the chief cause.

NOTE.—For convenience, as well as for ease of comparison, details of World War I personnel and training and of equipment are discussed in the chapters dealing with these subjects in World War II (pp. 19 and 45).

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Part II

ZONE OF INTERIOR

CHAPTER II

The Consultant in Radiology, Office of The Surgeon General

Colonel John A. Isherwood, MC (Ret.)

APPOINTMENT OF THE CONSULTANT

The Radiation (later Radiology) Branch, Office of The Surgeon General, was established on 12 July 1942 in the Surgery (later Surgical Consultants) Division, where it was under the direction of Maj. (later Lt. Col.) Michael E. DeBakey, MC, until 8 May 1943 (*1*). On this date, Lt. Col. (later Col.) Byrl R. Kirklin, MC (fig. 1), was appointed Consultant in Radiology (*2*), a position he occupied until 3 June 1946. Colonel Kirklin had a desk in the Personnel Division, Office of The Surgeon General, for several months before he was moved to the Surgical Consultants Division.

Colonel Kirklin served on active duty only part of the time. When he was not on active duty, as well as during a period of illness from 15 March until 1 June 1945, he handled many of his consultant functions from his private office at the Mayo Clinic. In particular, during these periods, he advised on qualifications and assignment of personnel and on the selection of X-ray equipment. He also reviewed papers and reports on radiology which had been submitted for approval before publication.

There could scarcely have been a better choice for this position. The late Colonel Kirklin, in addition to his clinical and technical eminence in his specialty, had a wide circle of friends among radiologists, and, as Secretary of the American Board of Radiology, Inc., had a wide knowledge of the qualifications of many other radiologists. These advantages, combined with his encyclopedic memory, fitted him admirably for one of his major responsibilities as consultant, Office of The Surgeon General; that is, the evaluation and assignment of radiologists to hospital and other duties. Conversely, his extraordinary memory has created difficulties in the preparation of the administrative history of radiology in the Zone of Interior in World War II: Colonel Kirklin had no assistants, he did not keep many records except in his head, and the circumstances in which he served meant that few files were kept for him. He died before he had begun to write the history of his tour of duty as Consultant in Radiology to The Surgeon General, and there are necessarily many gaps in the brief account of that mission in this chapter. Most of the material for it, in fact, is derived from his tours of inspection of

FIGURE 1.—Col. Byrl R. Kirklin, MC, Consultant in Radiology, Office of The Surgeon General.

the Second and Third Service Commands in November 1943 and of the Second, Fourth, Sixth, and Seventh Service Commands in December 1944 and January 1945, for which records do exist (*3*). Some of his associates have also kindly supplied certain details from their recollections. Their names are listed elsewhere.

Another difficulty in the preparation of this chapter concerns the reports from radiology departments of the various hospitals in the Zone of Interior. It was Colonel Kirklin's custom, on his visits, to ask for copies of the last monthly reports and of the average daily census. These concise data saved his time and the time of the hospital radiologists and other medical officers and permitted an intelligent discussion of many subjects. No uniform method of reporting radiologic data, however, was required, and in some hospitals no reports at all were made. Colonel Kirklin always suggested that these monthly reports be made up, on the basis of the sample form he circulated, but while the situation improved, the optimum was not achieved, and there are therefore gaps in this chapter which could not be overcome from these sources.

TOURS OF INSPECTION

Some confusion, never entirely clarified, existed concerning the responsibility for inspection of departments (sections) of radiology. As one of the

hospital professional services, these sections were also inspected by the surgical consultants in the various service commands, who also made reports on their efficiency and other matters. While he had no objection to these additional inspections, it was Colonel Kirklin's strong conviction that only a radiologist was properly qualified to evaluate the qualifications of other radiologists and that surgical consultants did not possess the specialized knowledge required for this function.

Colonel Kirklin's tours of duty covered a great deal of territory. In 1944–45, for instance, in his tour of the Second, Fourth, Sixth, and Seventh Service Commands, he visited 35 stations, including 18 general hospitals, 13 Army Service Forces regional hospitals, and 4 Army Air Forces regional hospitals.

Before his visits to the Second and Seventh Service Commands, Colonel Kirklin suggested to the command surgeons that a conference be arranged in each command, to be attended by as many radiologists as could be spared from their hospital duties. The Army Air Forces were invited to send their radiologists. Special subjects were assigned to special personnel before the conference, and the groundwork was thus laid for a free and thoughtful exchange of professional ideas. The discussions proved informative and stimulating.

These conferences were so successful that it was Colonel Kirklin's idea to use the same plan in all future tours. He could not put it into practice because of his illness in the spring of 1945, and the end of the war made other tours unnecessary.

He did not, however, regard conferences as a substitute for personal visits to individual hospitals. He regarded such visits as the only sound method of evaluating the total situation in respect to personnel, facilities, equipment, and type and amount of work.

Many of Colonel Kirklin's comments and recommendations are incorporated elsewhere in this book, particularly in the chapter on named general hospitals in the Zone of Interior (p. 119).

At the request of the commanding officers and radiologists in some of the hospitals he visited, Colonel Kirklin instituted the practice of sending information copies of his reports to them as well as to the surgeons of the service commands. His comments and recommendations were thus available for action.

EVALUATION AND ASSIGNMENT OF PERSONNEL

When mobilization began in earnest in 1941, many National Guard officers who were radiologists were not immediately assigned to hospital units. When the assignments were eventually made, they were not always as judicious as they might have been: Officers of unusual qualifications were sometimes placed in positions which did not make full use of their capabilities, while in other hospitals the reverse was true and officers of limited qualifications were

in charge of departments which demanded performances beyond their capabilities. On Colonel Kirklin's advice, all these officers were reclassified and reassigned to more appropriate positions.

As in other specialties, affiliated hospital units frequently had too much radiologic talent to be justified. Early in the war, some of these units had as many as three Board-certified radiologists, while some large station hospitals or nonaffiliated units had none at all. At first, since affiliated hospitals had been promised that their integrity would be maintained, no action could be taken to alter these inequalities. Later, in the interests of efficiency, the concentration of radiologic and other talent was dispersed, sometimes in the Zone of Interior, and, if not, when the hospitals were sent overseas, as all affiliated hospitals eventually were.

The staffing of induction centers, which was an extremely important matter, was also extremely difficult (p. 108). These were responsible positions, but many of the officers assigned to them lacked experience. The "Atlas of Chest X-Ray Films" prepared under the direction of Col. Esmond R. Long, MC (p. 109), was very helpful to these officers, and its existence somewhat simplified Colonel Kirklin's tasks.

Colonel Kirklin, as already mentioned, sometimes found that the radiologists of small station or other small hospital installations had qualifications better suited to general or large station hospitals. Mere size, however, did not sway his decisions and recommendations. Thus, in his report of his tour in the Second Service Command in November 1943, he noted that the radiologist at the Station Hospital, Fort Jay, N.Y., was too well qualified for a hospital of 360 beds, but he recommended that he be left in this position because the hospital served the personnel of Headquarters, Second Service Command, and its workload was heavy, 1,371 X-ray examinations in October 1943, 852 of which were in outpatients. At Tilton General Hospital, on the contrary, the amount of work did not warrant the retention of two radiologists, one Board certified and the other with very good training, especially as the hospital at nearby Fort Dix, Wrightstown, N.J., needed a second radiologist; the former had 2,400 beds, and 2,626 examinations had been carried out the preceding month.

Rank and promotion created the same difficulties in Zone of Interior installations as they did overseas. Colonel Kirklin called attention to many inequities. When Reserve officers were called to service, many of them well qualified, some of them Board certified, most of them with considerable time in the Reserve to their credit, they came in as lieutenants and captains, while other radiologists who came into the service later, with no previous military service, were inducted as majors. Such inequalities naturally generated discontent and ill will. Colonel Kirklin called attention to many of these inequalities and recommended that they be corrected.

Radiologists were usually correctly assigned and their duties were usually limited to radiology. There were occasional exceptions. At Thomas M. England General Hospital, Atlantic City, N.J., for instance, in 1943, Col.

James P. Cooney, MC, a Regular Army officer and a Board-certified radiologist, was serving as executive officer and lending a hand in radiology when his duties permitted, which was not very often. At an occasional station, such as the U.S. Army Dispensary at the New York Port of Embarkation, the radiologist combined his duties in that field with work in pathology and electrocardiography. This was a small station—only 176 examinations were made in October 1943—and his combined duties were simply a realistic approach to the situation.

Colonel Kirklin had a sympathetic understanding of the responsibilities and difficulties of medical officers who were serving as radiologists simply because there were not enough radiologists to fill all the positions.

Like all experienced radiologists, he also recognized the extremely important role of X-ray technicians. Careful investigation of their work and conferences with them were always part of his visits to hospital and other units.

Col. Paul A. Paden, MC, who served as Assistant to the Chief, Personnel Division, Office of The Surgeon General, during most of the war, has commented on the value of Colonel Kirklin's services in respect to personnel. With his remarkable memory, he said, and his knowledge of radiologic personnel all over the country, he was invariably able to place radiologists in positions commensurate with their ability. One of his first tasks when he inspected a medical unit was an evaluation of personnel from the standpoints of training, experience, propriety of assignment, and performance. His comments on personnel were always fair and generous but entirely frank. He was as willing to recommend assistance when it was needed, Colonel Paden concluded, as he was quick to advise transfer of personnel when he considered a department overstaffed.

GENERAL COMMENTS

Colonel Kirklin's comments (like those of the surgical consultants who also made visits of inspection) on the work of the departments of radiology in Zone of Interior hospitals and other installations were generally favorable and often highly favorable. Adverse comments, as a rule, dealt with details that could readily be corrected. In one general hospital, for instance, he found that definitive treatment of casualties was being delayed, sometimes as long as 14 days, because of the backlog of examinations in the X-ray department. More efficient methods were at once worked out. In a number of hospitals, he found that fluoroscopic machines were installed on medical wards and were being used by personnel without radiologic training. He always recommended that these machines be removed to the radiology department (or declared excess) and that, for medicolegal and other reasons, neither radiologic nor fluoroscopic units should be operated except by personnel with radiologic training.

Colonel Kirklin investigated the equipment provided in each installation and often made recommendations for supplemental items. He identified technicians capable of servicing X-ray machines and recommended their location where they would be most useful. When medical equipment maintenance officers were later stationed at supply depots, he was careful to make that fact known to the departments he visited.

He also noted that some general and regional hospitals were particularly well suited, because of equipment and personnel, to serve as training centers for inexperienced officers assigned to radiology or for officers who had expressed an interest in this field. In this report to The Surgeon General on his tour of inspection in November 1944 and January 1945 of hospitals in the Fourth Service Command, he recommended that all applications of officers appointed to the Army School of Roentgenology in Memphis, Tenn., thereafter be approved in the Office of The Surgeon General. The reason was his finding that one student then at the school was a diplomate of the American Board of Internal Medicine and another had been serving as internist and cardiologist at a named general hospital. To him, this was a waste of specialized personnel and of space in the school.[1]

[1] Could a roll be taken, it would certainly be the unanimous opinion of those radiologists who were visited by Colonel Kirklin during World War II that in any future war, as in part of World War I, there should always be a full-time Consultant in Radiology in the Office of The Surgeon General.—K. D. A. A.

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CHAPTER III

Personnel and Training

Colonel Alfred A. de Lorimier, MC

HISTORICAL NOTE

Training in the United States

Once the matter of X-ray equipment and supplies had been attacked, at least in its broad outlines in World War I, there arose what Col. George C. Johnston, MC, well called the graver problem of obtaining roentgenologists (*1*). Roentgenology, it must be remembered, was still a very limited specialty.

Before the United States entered the war in April 1917, the American Roentgen Ray Society had set up a Committee on Preparedness, and this committee, meeting in New York in the late spring of 1917, decided to call a meeting of leading roentgenologists in June at the Cornell University Medical College, New York, N.Y., to consider supplying radiologic personnel for the Army (*1–3*). At this meeting it was decided to establish a number of schools of roentgenology, all under the control of the War Department and each under the direction of an experienced roentgenologist who must be an officer in the Reserve Corps and on active duty. Medical officers would be assigned to the schools in groups of 10, and would receive instruction for periods of 2 weeks each before they assumed their duties. There would thus be uniformity in the teaching of all phases of radiology. After the officers had completed their courses of instruction, they would be ordered to New York for final examination and further instruction before being sent overseas.

Schools were promptly put into operation at Boston, Mass., New York, N.Y., Philadelphia, Pa., Baltimore, Md., Richmond, Va., Pittsburgh, Pa., Chicago, Ill., Kansas City, Mo., and Los Angeles, Calif. The courses given at them supplemented the course in radiology given at the Army Medical School, Washington, D.C., to all physicians who entered the Army. Training of enlisted men as "manipulators" (the technicians of a later day) was begun at the Army Medical School.

Six months after their establishment, these schools, having fulfilled their function, were closed, with the exception of the New York school. The teaching staff and facilities of the New York School of Roentgenology were augmented, and training of Reserve medical officers proceeded rapidly there. Technicians experienced in the installation and repair of X-ray apparatus,

who held commissions in the Sanitary Corps, were also given short courses of instruction at the New York school.

Part of the equipment of this school was the interrupterless X-ray unit designed by Maj. (later Lt. Col.) John S. Shearer, MC, which was so arranged that all wiring except that of the transformers was exposed (*4*). Student officers were required to familiarize themselves with the scheme of wiring and to become proficient in dismantling and reassembling the unit.

Meantime, after the closing of the first schools, other schools were established at the medical officers' training camps at Camp Greenleaf, Ga., and Fort Riley, Kans., for preliminary instruction in radiology. In May 1918, arrangements were completed for concentrating all X-ray instruction at Camp Greenleaf, and its staff and facilities were augmented for this purpose. The New York School was then closed and its apparatus was sent to the Camp Greenleaf School, which, it was planned, would turn out a minimum of 25 trained roentgenologists a month. A school for the instruction of manipulators was also established at Camp Greenleaf, two enlisted men being trained for each roentgenologist trained.

In September 1918, an alarming shortage of roentgenologists developed because hospitals were being sent overseas at twice the expected rate. At one time, there was not a single roentgenologist in the United States who could be ordered overseas. Plans were therefore made for the Camp Greenleaf School to train 120 roentgenologists and 150 manipulators a month, and the Personnel Division, the Surgeon General's Office, was asked to designate a certain proportion of medical officers for training in radiology.

Arrangements were also made to reopen the New York School of Roentgenology, under the command of Maj. (later Lt. Col.) Leon T. Le Wald, MC. A number of experienced radiologists were given short courses in the use of Army types of apparatus and in the localization of foreign bodies, then considered the chief concern of radiologists, after which they were employed as chiefs of section in the base hospitals in the Zone of Interior, the personnel of which had been depleted to supply oversea needs. After September 1918, base and evacuation hospitals under orders for overseas were each assigned one roentgenologist and two trained enlisted manipulators. Roentgenologists were no longer ordered overseas as casuals.

After the armistice was signed, the Camp Greenleaf School continued at full capacity, since hospitals in the Zone of Interior were still in need of radiologists (*3*). The original plan was to operate it until February 1919. Actually, it ceased to function at the end of 1918, when most of its equipment was sent to the Army Medical School. The New York School of Roentgenology was officially closed on 21 January 1919. In all, it had trained 214 nonradiologic officers in its regular courses and 58 in supplementary courses, as well as 11 experienced roentgenologists in certain phases of military roentgenology.

The course of instruction at Camp Greenleaf, which lasted 6 months was devoted entirely to military radiology. It included wiring of equipment;

processing of films and plates; training in exposure and development; and lectures and demonstrations concerning all aspects of X-ray diagnosis, with particular emphasis on the localization of foreign bodies. Instruction covered all types of units, including British, French, and German as well as U.S. types, so that officers and manipulators would be prepared for whatever they might encounter. In the summer of 1918, 57 student officers and twice as many manipulators were in training, and a darkroom was installed in which, using tray developers, 64 persons could work at one time.

When the Camp Greenleaf School closed, Lt. Col. William F. Manges, MC, who commanded it, was instructed by the Division of Roentgenology, the Surgeon General's Office, to prepare a very complete statement of the activities of the school, with photographs, drawings, digests of lectures, and abstracts of curriculums, "so complete that it will be possible if necessary to arrange for its reproduction, for any medical officer trained in Roentgenology to reerect this institution complete in every detail" (*2*).

In the confusion that followed the armistice, many officers were discharged by their commanding officers at various camps and hospitals; personal pressures had much to do with the discharges. In many instances, radiology departments were left without competent supervision. All commanding officers were therefore notified by the Office of The Surgeon General to discharge no more radiologists without authority of the Division of Roentgenology. Shortages were overcome when radiologists began to arrive from overseas, and by 1 March 1919, 201 were on duty in U.S. military hospitals of all types. At this time, 325 were still on duty overseas, 136 had been discharged, and 82 student radiologists had been released, a total of 744 (*2*).

A circular letter was sent to all roentgenologists requesting a statement of their desires as to discharge. Of those who had served only 3 months, 100 percent requested immediate discharge; of those who had served 6 months, 52 percent requested discharge; but of those who had served 20 months, only 20 percent wished to leave the service at once.

It was Colonel Manges' conclusion that, in the event of another war, special instruction in military roentgenology should be provided by Regular Army officers rather than by the Reserve officers, by whom it was given in World War I.

Oversea Training

All roentgenologic officers, even those who had had special training in the schools in the United States, were given additional instruction in France, at first in the X-ray repair shop in Paris, later at a school at the hospital center in Bazoilles (*2*). Some groups were instructed at Tours, by medical officers of the French Army. In all, 10 teams were assigned to the French Army for temporary duty for training in practical techniques. Some women assistants (manipulatrices) were taught by Madame Curie.

THE INTERIM BETWEEN THE WORLD WARS

In the early 1920's, the Army instituted a 9-month training program for officers newly commissioned in the Medical Corps, the Dental Corps, and the Veterinary Corps. Shortly after they were commissioned, and always before they were eligible for promotion to captain, these officers were sent to the Army Medical School in Washington for a comprehensive 4-month professional review course in medicine, dentistry, or veterinary medicine, followed by a 5-month period of training and indoctrination at the Medical Field Service School newly established at Carlisle Barracks, Pa.

The professional review course in medicine conducted in Washington, which was exceptionally comprehensive, provided training in subjects not available in many medical schools. From 50 to 80 student officers attended each course. The course in radiology, depending upon a number of factors, varied from 18 to 36 hours. Some instructors believed—and taught accordingly—that the X-ray curriculum should be limited to the use of field X-ray equipment, the diagnosis of fractures, and the localization of foreign bodies. Other instructors favored a far more comprehensive coverage.

In addition to the courses for officers, the Army Medical School also provided instruction for enlisted technicians of the Medical, Dental, and Veterinary Services. Between 30 and 60 technicians attended the courses, which were often of longer duration than those for officers; some of them lasted for a full year.

Many very competent enlisted technicians were graduated from the school. Unfortunately, however, the screening process for admission was not uniform, and as a result, men with no more than grammar school backgrounds were sometimes enrolled in classes in mathematics, physics, and chemistry for which, even though the instruction was elementary, they were totally unfitted. These men were soon eliminated. Other instruction included anatomy, physiology, the use of X-ray machines and related apparatus, and analysis of the wiring of the apparatus. A portion of the course was devoted to practical instruction at Walter Reed General Hospital, Washington, D.C.; here the technicians served apprenticeships and received training in the roentgenologic care of patients.

Technicians were also taught typing (fig. 2), with the objective of aiding radiologic officers in keeping clinical records and relieving them of some of their paperwork. The motivation was laudable, but once higher authority learned that medical technicians had been taught this skill, they were often spirited off to full-time typing assignments and never again saw an X-ray machine.

THE MOBILIZATION PERIOD

During the first stages of planning for large-scale mobilization in 1939 and 1940, requests for special lectures and presentations on radiology in a worldwide war were received almost weekly in the Department of Roentgen-

FIGURE 2.—X-ray technicians being trained in typing, Army Medical School, Walter Reed General Hospital, Washington, D.C.

ology at the Army Medical School. To meet the demand, lectures were prepared in advance and kept in readiness for distribution.

During the same period, at the direction of The Surgeon General, a short course was prepared on the duties and responsibilities of a roentgenologist at an induction station. A little later, 2-week special courses were conducted for groups of 10 to 20 medical officers.

It soon became clear that efforts such as these would not be adequate for the task that lay ahead. Many trained radiologists were volunteering their services, and some had already come on active duty, but their numbers were not proportionate to the indicated requirement, and it was obvious, even before the United States entered the war, that more active measures must be instituted.

STATEMENT OF THE PERSONNEL AND TRAINING PROBLEMS

The situation, as it was then developing, was summed up comprehensively by Lt. Col. (later Col.) Alfred A. de Lorimier, MC (fig. 3), at the twelfth annual conference of the American College of Radiology, meeting with clinical teachers of radiology, in Chicago on 15 February 1942, as follows: [1]

[1] Colonel de Lorimier's remarks at this meeting (5), while summarized, are presented at some length, not only because they indicate the requirements for radiologists at this time but also because they are a clear exposition of the thoughts of the man who was to direct the Army training program for radiologists and technicians throughout the war years and of the principles that guided him in that task. As a matter of convenience, Colonel de Lorimier's description of the courses already underway at the Army Medical School is presented elsewhere (p. 26).—K. D. A. A.

1. The Army has need for more roentgenologists at this time. The need, which appears to be in excess of the number now recognized as qualified and available, can be explained by the fact that when medical and surgical services must be accomplished under conditions of stress that prevail in a combat zone, the roentgenologist, in addition to strictly roentgenologic duties, must assume a large measure of the diagnostic duties ordinarily handled by the general practitioner and by the internist and other specialists. During combat, casualties will be received in large numbers, and diagnoses must be made within a minimum of time.

2. What cannot be seen by external viewing will be sought by roentgenologic examination, which will be used even more than during World War I: Today, in addition to general fluoroscopic procedures for study of the skeleton, X-ray examinations are accepted as the most reliable means of diagnosing abnormalities in the abdomen, the chest, and the skull.

3. Localization of foreign bodies perhaps may not be required as frequently as in World War I because the science of ballistics has so changed that today missiles have greater penetrating characteristics, and many wounds will probably be handled at once by surgical debridement, chemotherapy, and closure, without roentgenologic assistance. Nonetheless, a considerable demand for fluoroscopy is to be expected, and no doubt there will be some foreign body localization. It needs no more than one case to emphasize the fallacy of the policy of initiating surgery without X-ray assistance. [2]

4. Roentgenology will probably be utilized to an extent proportionately greater than is required in general civilian care. For this reason, the number of radiologists is disproportionately less than the number of other specialists. The shortage which exists must be met by special training. For certain assignments, however, this training need not be as complete as would be considered essential for a well-rounded radiologist, or sufficient to meet the requirements of the American Board of Radiology.

5. Certain fundamentals, nonetheless, must be insisted upon. They are based on a consideration of the functions to be expected of the roentgenologists assigned to special medical installations, with specialized missions, which may vary from time to time or from day to day. The rapidity of troop movements, the frequent changes in the battle front, and the alterations of offensive and defensive tactics make it impossible to consider any hospital assignment as permanent.

6. Roentgenologic units are not included in a combat division. The most forward medical installation at which roentgenologic assistance can be utilized effectively is the field (surgical) hospital, in which nontransportable casualties are handled. [3] These hospitals are expected to perform as many as 80 major surgical operations each 24 hours. Present plans call for the assignment of two roentgenologists (a lieutenant and possibly a captain), assisted by three enlisted X-ray technicians. During periods of considerable stress, both roentgenologists will probably be engaged in fluoroscopy. Some of this work may be accomplished in a closed truck, but in many units and installations, some, or perhaps all, of it will be accomplished in fluoroscopic tents.

When the operating section of a surgical hospital moves forward, the holding section left behind is equipped with a fluoroscopic tent, an X-ray machine unit, and a field table

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[2] Colonel de Lorimier's prewar analyses and predictions were quite remarkable and generally correct. The foreign body localization table, however, was used very little in World War II for its intended purposes. In retrospect, it would have been more useful if it had been equipped with a light Bucky and if it had been adaptable to upright use. Most foreign body localization overseas was accomplished by 90° radiographs, which could be carried into the operating room. Another incorrect prewar prediction concerned the expected use of radiation therapy; it was practically never used for infection, even for gas gangrene, being supplanted by surgery, the sulfonamides, and, later, penicillin.—K. D. A. A.

[3] Space does not permit the inclusion of the detailed description Colonel de Lorimier gave of the special missions of each of the hospital installations whose radiologic functions he described. His whole presentation was very useful to an audience of radiologists who knew little or nothing of military medicine, including military roentgenology.—K. D. A. A.

FIGURE 3.—Col. Alfred A. de Lorimier, MC, Commandant, Army School of Roentgenology, University of Tennessee, Memphis, Tenn.

unit. The roentgenologist who accompanies the operating section will usually confine his activities to general fluoroscopy and foreign body localizations. The one who remains with the hospitalization platoon will be called on for fluoroscopy, or possibly roentgen ray therapy for infections.[4]

7. The evacuation hospital, which is expected to be from 30 to 70 miles behind the frontline, will accommodate as many as 750 casualties. Two roentgenologists (a captain and a lieutenant) and as many as 10 technicians (three sergeants and seven privates) are assigned to it. Fluoroscopy will be employed in perhaps 90 percent of the casualties and roentgenography in perhaps 10 percent. Equipment for the evacuation hospital therefore must include some films, a film processing unit, and a film dryer unit. The darkroom tent used for fluoroscopy at the field hospital can be adapted for film processing, and several of them will be supplied. Roentgenologists at the evacuation hospital must be competent to handle general fluoroscopic procedures, foreign body localizations, diagnostic radiology, and superficial radiation therapy. In both the field and the evacuation hospital they must be self-reliant and resourceful and prepared to render quick judgments.

8. A convalescent hospital set up near an evacuation hospital may accommodate as many as 3,000 patients, but will require less active roentgenologic support than field and evacuation hospitals. Only one roentgenologist (captain) and 5 technicians are assigned to this installation: the assistance of the more senior roentgenologist of the nearby evacuation hospital is utilized for serious problems.

9. A general hospital, which provides definitive care, is completely equipped, usually with from four to eight portable and mobile units and 1 or 2 high-milliamperage-capacity machine units (a 2-tube, 300-ma. unit and a 1-tube, 200-ma. unit) complete with tables

[4] See footnote 2, p. 24.

and various auxiliary items. For each thousand patients, three roentgenologists and nine X-ray technicians are allotted: they are expected to provide practically any service required in a well-organized civilian hospital. At least two of the roentgenologists must be well qualified; if the hospital is isolated, both should be able to meet the requirements of the American Board of Radiology, Inc. Additional radiologists would be required in an aggregation of general hospitals forming a hospital center, but not all of them need possess the range of qualifications just stated. Some of them might be assigned limited activities, such as are performed by fellows in radiology in teaching institutions.

10. One radiologist would be assigned to each station hospital with a bed capacity in excess of 250. He would have diverse responsibilities. For a 500-bed or larger installation, a well-qualified roentgenologist, with the rank of captain or major, would be assigned.

At this time (February 1942), 2- and 3-month courses in roentgenography were being given for technicians at the Army Medical Center, with a monthly quota of 40; at Fort Sam Houston, San Antonio, Tex., and at the Fitzsimons General Hospital, Denver, Colo., and at William Beaumont General Hospital, El Paso, Tex., with a monthly quota of 15; at the Army and Navy General Hospital, Hot Springs, Ark., with a monthly quota of 10; and at Letterman General Hospital, San Francisco, Calif., with a monthly quota of 6. Provision was thus made for the training of X-ray technicians at the rate of 101 per month. Accommodations were being increased, and it was expected that increments of 1,500 technicians could be provided annually. In addition, a school for training Women's Army Corps technicians had been established at Wakeman General Hospital, Fort Benjamin Harrison, Ind.

The course at the Army Medical School, formerly recognized by the National Registry of X-Ray Technicians, had recently lost this recognition, but in Colonel de Lorimier's opinion, the decision to withdraw accreditation could not be criticized. At the present time, training was necessarily hurried and of a didactic character. It was not possible to develop fully competent technicians, with a wide range of practical experience, in these circumstances. For this reason, the military roentgenologist must be prepared to train and supervise his own technicians and must be prepared, because of his own transfer or their transfer, to lose them once they were trained.

TRAINING IN ROENTGENOLOGY AT THE ARMY MEDICAL SCHOOL

At the twelfth annual conference of the American College of Radiology, meeting with clinical teachers of radiology, in Chicago on 15 February 1942, Colonel de Lorimier also outlined the training in radiology then being provided for medical officers at the Army Medical School. Two courses were given in alternate months:

1. The shorter of the courses, which lasted 2 weeks, concerned the special examinations conducted at induction centers (p. 110). It was intended for qualified roentgenologists and dealt entirely with particular applications to photoroentgenology and to induction regulations.

2. The longer course, which occupied 192 hours over a 4-week period, provided emergency training for the approximately 500 radiologists who, it was believed, would not require a wide range of roentgenologic knowledge or experience but who would have important duties as assistants in theaters of operations. From 40 to 80 medical officers attended each of these courses. At this time it was thought that most of the necessary training could be accomplished within the Army itself, though it might later be found that the Army Medical School could not carry the total load.

This course (appendix A, p. 923) consisted of 133 hours of didactic lectures; 12 hours of conferences; 44 hours of investigations of special problems; and 3 hours of examinations. Instruction was intensive, occupying 8 hours a day for 6 days a week.

During the course, 6 hours were spent in identification of controls (7 types) for both mobile and stationary units. All instruction was supplemented by demonstrations, and presentations were designed to provoke discussion. Attentiveness on the part of the students was enforced by frequent questions.

No time was allotted for positioning of patients or for actual roentgenography. These phases of the subject were covered by TM (War Department Technical Manual) 8–240 (*6*).

When the training courses were instituted, several older roentgenologists, who had had experience in World War I, argued that the teaching material should include only fundamental physics, the design and functioning features of field X-ray equipment, foreign body localization, and fractures, on the ground that this material was all the student officers could be expected to assimilate. Colonel de Lorimier, however, who had the responsibility for the course, did not agree. He had had training under Col. William LeR. Thompson, MC, in a refresher course at the Army Medical School in 1931, and it seemed to him far more prudent to follow the principles and policies currently in use at the Medical Field Service School. Here, teaching consisted of lectures, demonstrations, and practical instruction, plus scanning of the entire field of radiology. This teaching method stimulated medical officers in their studies and imbued them with a respect for the scope of the specialty, a respect which otherwise was likely to be lacking. Colonel de Lorimier remembered particularly Colonel Thompson's portrayal of what he called "scientific criteria."

In the diagnostic teaching at the Army Medical School, general procedures were described and demonstrated and roentgenographic studies were presented by means of lantern slides. Both direct and indirect roentgenologic evidence was described. It was emphasized that the roentgenologist should analyze the film:

1. By an orderly study of the evidence shown by it, with a listing of roentgenologic criteria.

2. By a consideration of what collaborative evidence might be obtained by roentgenologic studies of other portions of the body.

3. By a consideration of the implications of such factors as the age, sex, nationality, and race of the patient in relation to the general incidence of the suspected conditions.

4. By a review of the clinical history, the physical findings, and the laboratory data.

Instruction at the Army Medical School stressed the scientific aspects of roentgenology; cases were never presented for diagnosis on the basis of what a condition "looked like." Instead, detailed diagnostic criteria were described and demonstrated by films or slides. The emphasis on diagnostic criteria was enhanced by the conferences at the Army Medical School every Saturday afternoon from 2 to 5 o'clock. At them, Colonel Thompson, then Chief,

Radiology Section, pointed out the discernible roentgen criteria which lead to diagnosis, and he correlated clinical, laboratory, and, when available, histopathologic findings with the roentgen findings. It was always emphasized that the roentgenologist was a consultant and as such must not limit his observations to films. The best roentgenologists were investigative scientists in their own right.

CIVILIAN CRITICISM OF THE ARMY TRAINING PROGRAM

Almost from the beginning, rumblings of dissatisfaction with the Army's training program for radiologists began to be heard. Some radiologists thought the program too modest in terms of output. Some thought the time allotted to the course too brief to produce trained radiologists and were highly critical of what they called "de Lorimier's 8-week wonders." Some thought that the training task could be performed better in civilian medical schools. One eminent radiologist, writing to another professor of radiology, expressed these criticisms in the the form of questions and answers, which, in substance, covered the following points:

1. It is expected that the medical officers assigned to 28-day courses in radiology at the Army Medical School will continue their training under diplomates of the American Board of Radiology, Inc., serving as chief radiologists at the hospitals to which they will be assigned. There are several objections to this plan, although fundamentally it is sound: The majority of diplomates of the Board have had little or no teaching experience. Army hospitals are not ideal places for such training, even under the finest quality teachers. The total number of radiologists who can be trained by this means will probably be inadequate.

2. Civilian centers, with the vigorous support and cooperation of the Government (but not without it), could do much to augment the supply of radiologists in training for the Army. The first step would be to persuade Selective Service and the Procurement and Assignment Board to make it possible for able-bodied young male physicians to continue in radiology for 2 years after completion of their internships. The usual 3-year course in radiology could be reduced to 2 years if therapy, pediatrics, obstetrics, and gynecology were deemphasized and if hours were lengthened and other means of speeding up instruction were employed.

At his own university, the writer continued, the output of radiologists could soon be 150 percent of the men being turned out before the war emergency instead of 16 percent as at present. Moreover, 12 or 14 men could be in training at one time at this university, instead of the present 6, if the Government would provide radiologic fellowships, or some other form of subsidy, for any number accepted beyond these 6. Another plan, perhaps preferable from the Army standpoint, would be to assign 6 to 8 medical officers for 2-year periods to this institution. Since it was unlikely that medical officers would ever be assigned for 2-year periods of training, a compromise of 9 months might be worked out.

3. Training should be practical, not didactic. The men in training should be put to work in a busy X-ray department, under civilian radiologists, and should be given responsibility as fast as they could assume it. They could participate in the formal work organized for other trainees, but their real training would be in daily contact with X-ray work. There is a fundamental difference between training in the X-ray department of a newly organized and understaffed Army hospital and an apprenticeship in the X-ray department of a long-established teaching center.

4. To the writer, two objectives were important:

A. Existing subsidized training positions in radiology should be occupied by young male physicians who were looking forward to a commission in the Army rather than utilized by militarily unacceptable candidates.

B. The Army should be induced to provide intensive training in civilian institutions for at least 9 months for subsidized and exempted male civilian physicians or commissioned medical officers.

5. The greatest difficulty in the way of such a program is the wholly unjustified fear that there might be a plethora of radiologists after the war. This is, of course, a fear that deserves no consideration during the war. Regulations can be changed and new traditions established if once Army authorities could be convinced of the acute need for radiologists in Army hospitals.

Although the letter just summarized represented a viewpoint held by some civilian radiologists at this time, The Surgeon General did not agree with them, and the Army School of Roentgenology, Memphis, Tenn., continued to function according to the scheduled program during the remainder of the war.

RELOCATION OF SCHOOL

Selection of New Location

During the latter part of 1942, with increasing mobilization, the teaching requirements of the Department of Roentgenology expanded well beyond the physical capacities for their accommodation at the Army Medical School in Washington. Furthermore, the city had become so congested that housing of officers and enlisted students had become a difficult problem. Decentralization was clearly necessary, and the Director of the Department of Radiology at the school was therefore ordered to investigate the possibility of moving the radiologic section out of Washington, bearing in mind the following requirements:

1. Adequate classroom space for lectures and demonstrations, including sufficient leadlined areas.
2. Adequate housing facilities for officers and enlisted students as well as for the cadre.
3. Nearby hospital facilities for clinical observations, study, and training. It was regarded as most important that clinical facilities be available for case studies and roentgenoscopic practice for officer trainees and for practical work by enlisted trainees.
4. A reasonably favorable climate, to facilitate such outdoor training as might be necessary.

The most promising locations available at this time, or to be available shortly, were at Boston College, Boston, Mass.; Woodrow Wilson General Hospital, then under construction at Staunton, Va.; Nichols General Hospital, then under construction at Louisville, Ky., Kennedy General Hospital, then under construction at Memphis, Tenn.; Thayer General Hospital, still in the blueprint stage of planning at Nashville, Tenn.; and Ashford General Hospital, then being converted from the Greenbrier Hotel at White Sulphur Springs, W. Va.

Of these locations, Ashford General Hospital seemed the most practical from every standpoint. Its 7,000 acres suggested that the Army School of

Roentgenology, if once established, might remain permanently in this location and that other elements of the Professional Service Schools program, and even of the Medical Field Training School, might later be added. Little reconstruction of outlying buildings would be required for the accommodation of teaching personnel and trainees. Moreover, the location was only 6 or 8 hours' travel from Washington, D.C., and the transportation of heavy X-ray equipment from the present school would thus be greatly simplified.

These plans were blocked by the commanding officer of Ashford General Hospital, who considered that all the facilities available would be needed for battle casualties. When the possibility of locating the Army School of Roentgenology at Kennedy General Hospital was next explored, its commanding officer took the same position.

It was very much by accident that the Army School of Roentgenology was finally located on the campus of the University of Tennessee College of Medicine in Memphis, Tenn. Because of a delay of some 6 hours in train connections while he was on an inspection tour, Colonel de Lorimier visited the X-Ray Department of the John Gaston Hospital, in charge of Dr. Hillyer Rudisill. Dr. Rudisill became much interested in the possibility of locating the School of Roentgenology at the University and promptly arranged for Colonel de Lorimier to meet with the Dean of the Medical School, Orren W. Hyman, Ph. D., who displayed an equal amount of interest. Interest by other University authorities was considerable, and the Army was encouraged to investigate the matter thoroughly.

A second inspection tour by Colonel de Lorimier and Lt. Col. (later Col.) Daniel J. Sheehan, MC, Deputy Director, Training Division, Office of The Surgeon General, showed that the campus of the University of Tennessee College of Medicine had practically all the features of other locations considered, and it was decided to locate the Army School of Roentgenology at the University (fig. 4) under the following conditions:

The school would be located at Eve Hall at the nominal rental of $100 per month, heat to be provided under the terms of the lease. Since this building was on lease by the city to the University, negotiations for its use had to be conducted with the mayor of Memphis and the city and county commissioners.

The building to be used as a barracks was rented for $1,250 per month, all utilities being furnished. The University was at first most unwilling to release this building, but other buildings, located almost as conveniently, were unacceptable for one reason or another (chiefly high rentals and the cost of repairs of damage caused by termites), and the dormitory was secured only after the whole project was about to founder.

Mess facilities would be provided in the cafeteria of the university center. Adjacent ground would be available for drill and recreational facilities. Climatic conditions in Memphis were favorable for these activities during practically all the year.

Army personnel would have the use of the University Library. Hospital training facilities would be provided at the John Gaston Hospital, at a nominal rental of $1.00 per year, with the understanding that Army X-ray equipment would be used and Army personnel would provide diagnostic and other roentgenologic services. Since this was a municipal hospital, negotiations for its use had to be conducted with the city authorities.

FIGURE 4.—Aerial view of Army School of Roentgenology, University of Tennessee, and adjacent areas. (1) College of Medicine. (2) Army School of Roentgenology in Eve Hall. (3) Barracks for enlisted technicians. (4) University Center, containing messhall. (5) John Gaston Hospital. (6) Baptist Memorial Hospital. (7) Willis C. Campbell Clinic.

ACTIVATION OF THE ARMY SCHOOL OF ROENTGENOLOGY AT THE UNIVERSITY OF TENNESSEE

Orders called for the movement of the Army School of Roentgenology from the Army Medical Center to Memphis on or about 29 December 1942. One class of officers and one class of enlisted trainees were graduated as of this date. The two other classes of enlisted men then in training, numbering 72, arrived in Memphis by train on 2 January 1943.

Two weeks earlier, Maj. Carl E. Nurnberger, SnC, and Capt. (later Maj.) John R. Hannan, MC, together with two enlisted assistants, arrived in Memphis and coordinated with the Corps of Engineers in the reconstruction of Eve Hall. Equipment was transported in 17 large vans and arrived on 3 January 1943.

Classes were to be resumed on 4 January 1943, and a class of 97 officer trainees and a new class of 35 enlisted trainees arrived the preceding day. At this time, only the first floor of the school building was in readiness, but the university provided space for classes for the next 2 weeks, and instruction therefore began as scheduled.

FIGURE 5.—Eve Hall, in which instruction was carried out.

Colonel de Lorimier served as commandant of the Army School of Roentgenology, assisted by Maj. (later Lt. Col.) Henry G. Moehring, MC, as director of the officers' course in diagnostic radiology; Maj. (later Lt. Col.) Joe C. Rude, MC, as director of the X-ray course for enlisted technicians; and Capt. (later Maj.) Carl E. Nurnberger, SnC, as chief of the Research and Development Laboratory for Field Service X-Ray Equipment (p. 89).

True activation of the school was, of course, not as simple as publishing orders for it, and the first days were taken up with the myriad of details, the large and small decisions, and the physical labor involved in any new organization. Under the stimulus of a great war and the known urgent need for radiologists and technicians, all concerned in the project worked with unstinted effort, and in a surprisingly short time the school was a smoothly working unit.

Physical Plant

School.—Eve Hall (fig. 5), which housed the school proper, was a rather old 4-story building containing about 12,000 sq. ft. of floor space. The first floor was devoted to a laboratory with eight leadlined cubicles for mobile X-ray machines (fig. 6), two cubicles and two separate rooms for high milliamperage units, a film processing room, a film storage room, and the person-

FIGURE 6.—X-ray laboratory, divided into protected cubicles

nel and transportation offices. The second floor housed offices, lecture rooms, and a war room for enlisted students. The third floor contained a large lecture hall, an art section, a photographic section, and additional offices. The fourth floor contained another large lecture room, a library and seminar area, a roentgenographic section, a film interpretation section, a stereoscopic section, a maintenance and repair shop, a darkroom tent for foreign body localization, a testing and research laboratory, and an officers' war room.

The physical arrangement of the school indicates the diversity of facilities required and makes clear the practical nature of the instruction. It should be emphasized that all possible protective measures were taken. Each of the panels of the cubicles on the first floor contained 1 mm. thickness of lead. The working area of each cubicle, exclusive of aisle space, was 10 by 15 feet. All controls were provided with lead protection anteriorly.

Barracks.—The dormitory adjacent to Eve Hall, which served as a barracks (fig. 7) was a large (20,000-sq. ft.) building, rather more modern than the school. It was used for housing enlisted students and the cadre, and for supply and detachment headquarters and other housekeeping necessities. Its population ranged between 100 and 260 enlisted men as the school population ebbed and flowed.

No housing was provided for student officers or officers on the school staff, but local civilian housing proved entirely satisfactory.

Messing facilities.—The mess for students and staff, located in the university center building (fig. 8), was operated by the university dining service under contract with the U.S. Government.

Hospital facilities.—About a thousand square feet of space recently vacated by the Department of Bacteriology, was leased in the east wing of the

FIGURE 7.—Barracks for enlisted students.

John Gaston Hospital (fig. 9) and used for instruction in X-ray techniques for enlisted technicians. The real consideration of the lease was the provision by the Army of supplies, equipment, and X-ray service for the hospital, while the Army, in turn, was able to provide for its trainees excellent on-the-job instruction, which was far better than dry runs. The exposed films became the property of the hospital and part of the patients' clinical files.

Because of conversion difficulties, it was some 6 months after the school was activated before the X-ray clinic of the John Gaston Hospital could be used for training. The difficulty, which could have been quite serious, was overcome by the staffs of the Baptist Memorial Hospital and Willis C. Campbell Clinic, both in Memphis, Tenn. (fig. 4) :

Drs. J. Spencer Speed, Harold B. Boyd, and Joseph F. Hamilton of the clinic invited the teaching staff of the school to participate in their regular Monday evening conferences. Within a short time, these conferences were being conducted in the officers' lecture room at the school. They constituted the finest possible presentations for the officer trainees. Each presentation consisted of a clinical abstract; demonstration of films, with discussion by one or another of the instructors of the school; then a general discussion of therapy; and, finally, projections of microscopic sections or gross specimens when they were available.

In a comparable fashion, current roentgenologic problems were presented at Saturday afternoon conferences by Dr. John E. Whiteleather of the Baptist Memorial Hospital. These activities began almost immediately after class instruction was started and continued through the period the school was in operation. Lt. Col. (later Col.) Justin E. McCarthy, MC, from nearby

FIGURE 8.—University center, where messing facilities were provided.

Kennedy General Hospital, conducted similar conferences, as did other visiting radiologists.

It is impossible to overestimate the value of the cooperation of all of these physicians and officers in the instruction at the School of Roentgenology.

Library facilities.—Students at the school had unlimited access to the Library of the University of Tennessee College of Medicine (fig. 10), which contained over 30,000 volumes. Books could be used in the library or signed out for as desired.

Drill and recreational facilities.—In front of the dormitory (barracks) was a large plot of land, where reveille and retreat ceremonies were held. It is doubtful that local citizenry fully appreciated the sounding of the bugle at reveille at 0600 hours 7 days a week, but their attitude toward retreat was quite different, and very often groups of citizens joined in the ceremony of honoring the flag at the close of day.[5]

The school also had the use of Forrest Park, a city square of land less than a block away, for drill and other field exercises. This square is the

[5] The professional staff of the University of Tennessee College of Medicine, the municipal leaders, and the citizens of Memphis generally received the personnel of the school with the greatest cordiality. There was scarcely a community gathering at which the school was not represented, and officers and enlisted men were also welcomed into local homes.

FIGURE 9.—John Gaston Hospital, Memphis, Tenn.

scene of lasting memories for some of the less militarily inclined of the student radiologists and technicians.

CURRICULUM

General Considerations

The Army School of Roentgenology was first and foremost a training institution (chart 1). It would have been easy, at times, to become so involved in the fascinating business of research that this main objective was lost sight of. It never was.

The level of the material presented in the medical officers' and enlisted technicians' courses naturally varied, but for both groups this school was an intensive educational experience, conducted by the same general principles:

As in other Army schools, the material was presented by lectures, demonstrations, and practical applications (fig. 11). As with the shorter courses conducted in Washington, every hour of a 6-day week was accounted for. The day began at 8 a.m. and continued until 5 p.m. Each lecturer was required to have his material well prepared, with written outlines, but reading the lecture was never permitted. Appropriate training aids, such as various items of apparatus, charts, and lantern slides were used. Later, the material presented was reviewed in seminars, and there was individual practice with equipment and in fluoroscopy, stereoscopy, and foreign body localization.

FIGURE 10.—Library, University of Tennessee College of Medicine.

Visiting speakers were utilized to the utmost, particularly professional men of the community and medical officers who had returned to the United States after tours of duty in theaters of operations.

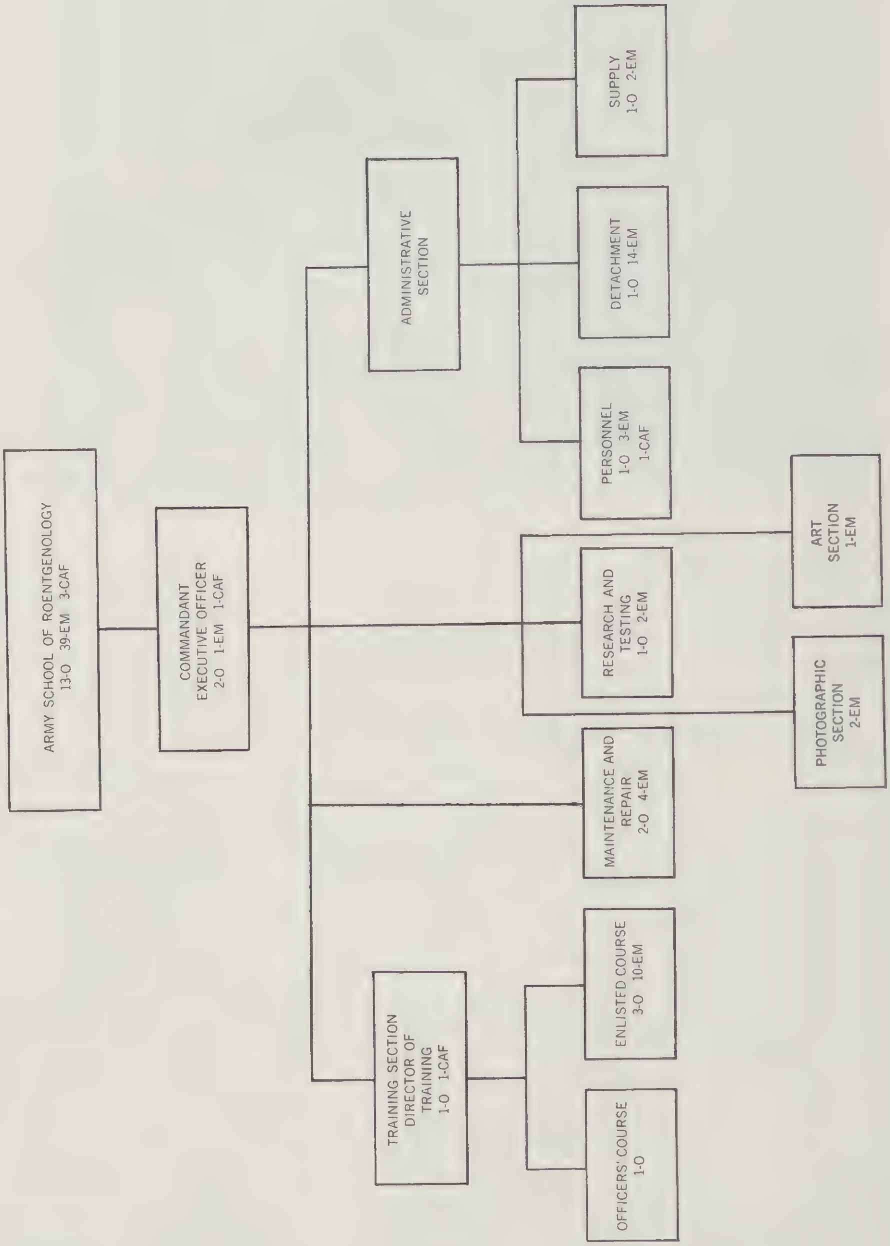
Written examinations served three purposes. They stimulated the student to review the material he had studied. They were a means of evaluating his comprehension of it. Finally, they helped to evaluate the quality of the teaching. Each examination consisted of 10 to 20 questions, not more than 2 or 3 of which were submitted by any single lecturer. If the majority of students answered his questions correctly, it was obvious that the teacher had made the subject clear. If most of them could not answer his questions, the teacher was likely to be at fault.

Each student was treated as an individual and after graduation was recognized as an alumnus of the school. This attitude paid off. Many enlisted students, as well as many officers, corresponded with the school after they had left it and often sent interesting and useful material from distant places, as well as many helpful suggestions.

Courses for Medical Officers

The principal course in roentgenology for medical officers, entitled "The Basic Course in Roentgenology," was an intensive, comprehensive course, lasting 12 weeks and ranging in subject matter from a review of basic physics and electricity through highly complex radiologic diagnostic techniques. In substance, the material was much the same as that taught at the Army Medical School, but the longer courses permitted more intensive instruction.

CHART 1.—*Table of Organization, Army School of Roentgenology*



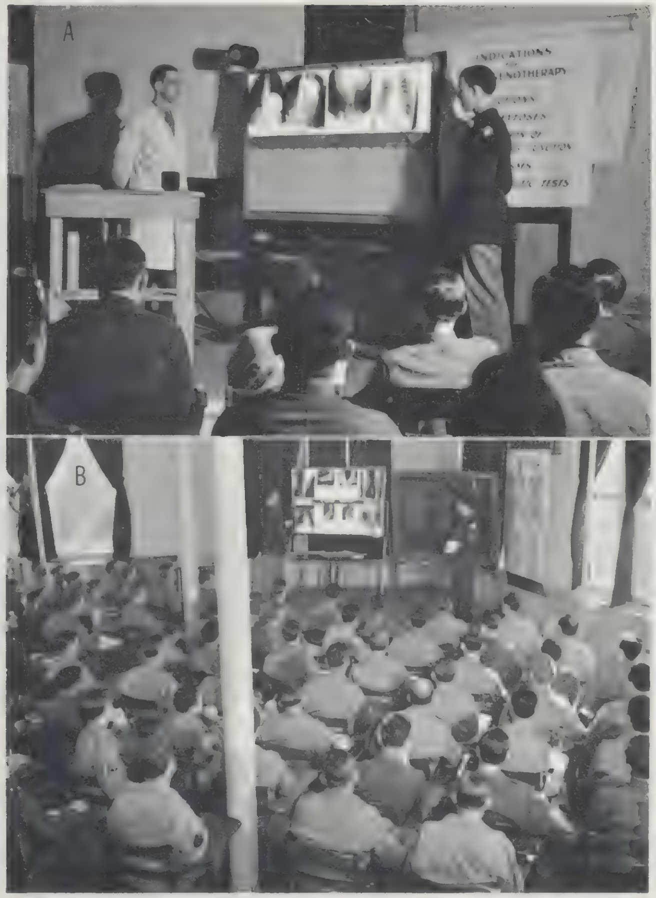


FIGURE 11.—Didactic instruction in Army School of Roentgenology. A. Seminar in diagnostic roentgenology being conducted by Lt. Col. Henry G. Moehring, MC, Chief, Clinical Section, Diagnostic Radiology. Note student officer pointing out radiologic criteria. B. Class of enlisted students receiving instruction on roentgenologic aspects of osteology. Maj. Maxwell Dauer, MSC, Senior Instructor in Clinical Roentgenography, is conducting the class, assisted by S. Sgt. William L. Schwerzler.

This schedule, of course, did not produce trained radiologists. At the very best, it simply provided a sound introduction to radiology for men with minds already trained in medicine. Upon this foundation, supplemented by the training given by the experienced radiologists with whom these officers later worked, a good understanding of radiology was built. One proof of the success of the school is the number of men trained at it who went on to careers in radiology after the war. In all, 887 medical officers were trained in the

Army schools of roentgenology, 581 at the school in Memphis and 306 at the Army Medical School.

The teaching staff, whose spirit was always remarkably high, had many obstacles to overcome. When one of the larger groups of officers was admitted, for instance, information was received from Washington that 34 of the group were pediatricians. The commandant challenged his staff to convert their pediatric interests to roentgenology, and in his introductory welcoming remarks, with his staff on the platform with him, he defied these pediatricians not to become interested in the X-ray course. For the next week or 10 days several of them performed their duties in a very desultory manner. Then, gradually, their attitudes changed, and they did their work with wholehearted effort and application. After the course was ended and all the ratings were compiled, fully half of the pediatricians dropped by the commandant's office to say their farewells and to comment that they had heard his opening remarks with a high degree of skepticism but were surprised to find how interesting and profitable their work had been. There is little doubt that they carried their new zeal into their assignments.

Courses for Enlisted Technicians

The curriculum for enlisted technicians included an introduction to the course; basic arithmetic; basic physics related to electricity and X-rays; production of X-ray equipment; component parts and functioning of military X-ray equipment; wiring diagrams; packing, loading, and setting up of equipment (fig. 12); processing of X-ray films; introduction to anatomy; introduction to osteology; positioning of patients for radiologic examinations; fluoroscopy; foreign body localization; gastrointestinal examination; and barium enemas. In addition to the radiologic subjects just listed, the course for enlisted men included ethics of medicine and of radiology; the organization and operation of the Army Medical Department; and military training.

A sample weekly schedule (appendix B, p. 926), indicates the scope and intensity of the course for enlisted men. By and large, they did very well, though their degree of success was related to the amount of their prior education. In a sample of 297 students, 100 percent of those with less than 8 years of education failed the course; high school graduates, generally speaking, did quite well; and there were no failures in students with 2 years or more of college education.

In all, 1,429 enlisted technicians were trained in the Army schools of roentgenology, 988 at the school in Memphis and 441 at the school in Washington, D.C.

FIGURE 12.—Assembly of lightweight combination field X-ray machine and table unit, which followed lectures on the functioning of each component part of this item. Later, each student individually was required to assemble and disassemble this unit and all other items of field X-ray equipment.

ADDENDUM [6]

The November 1942 class of the Army School of Roentgenology was probably typical. There were about 65 of us. A majority had been in military service only a few months; in grade there was a preponderance of first lieutenants; there were two majors; the rest captains. They had come from all over the United States. One lieutenant had just completed a residency in radiology, and was either American Board eligible or was recently certified. Two or three others had done some graduate training in radiology; a majority were relatively young physicians who had registered no special interest in radiology. But there was a real dearth of trained men for the military service and we had been sent by our commanding officers in an effort to supply the need. Some had requested the course and the request had been granted. These seemed to be in a minority. I recall no one who was regular army; we were either reservists or AUS.

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[6] Many of his former students attest to the remarkable scope and thoroughness of Colonel de Lorimier's basic course at the Army School of Roentgenology. "Three months there," one of them wrote many years later, "was as good as a year elsewhere," a comment which effectively disposes of the criticisms of the basic course made early in the war by certain civilian radiologists (p. 28). Theater senior consultants in radiology praised the work of the "Colonel's 90-day wonders," as these students came to be called.

This section can be appropriately closed with an affectionate, reminiscent note from one of Colonel de Lorimier's former students, the former Maj. Alton S. Hansen, MC, then a surgeon, now a certified radiologist. It is appended without editorial change.—K. D. A. A.

We were duly impressed with the school. Colonel de Lorimier approached the business of teaching us as much as possible in a four week period in a distinctly serious vein. At 0800 on the first Monday morning we assembled in the main lecture room. It was at basement level, austere; quite crowded. Seats were assigned; from the roll the Colonel wanted to be able to identify us. Within a few days we found out why.

During the first week the Washington weather was mild for November and then it turned cold. There must have been some steam radiators in that room but there was no steam. The heavy class A uniform over heavy duty underwear maintained warmth for all parts except hands and feet. They stayed cold for the rest of the month.

In the first lecture, the Colonel reviewed the experience of the October class; the one immediately before us. It seemed that they were a fine lot of men, but not to be considered as serious students and the Colonel was nettled. About half of them had not performed satisfactorily, as demonstrated in the oral and written examinations, and their commanding officers had been notified. This was not a cause for disciplinary action, but it obviously was a cause for embarrassment and certainly contributed nothing toward that advance in grade which was such a desirable thing. He made it clear to us that anyone not applying himself to a point of total diligence would forthwith be returned to his unit. The Colonel pointed out that we were at war, and our sacrifice in time and energy must be accelerated in every detail or we would fail in our effort; witness the fall of France! At about this point the Colonel diverged completely from the subject of roentgenology and delivered what we later came to call the classic lecture on "the fall of France." Clemenceau or Foch could not have orated better; none of the more recent French leaders could have come close. The Colonel held to the proposition that every citizen of the United States must be willing to make a total effort to win the war. None of us could argue against that, and we loved him for it; and no one in that group failed!

For the most part the lectures were of fifty minutes duration with a ten minute break. Or was it five? From 0800 to 1200 and from 1300 to to 1700. Many evenings there were special sessions of two hours; these were a little later in the course. Once each week we attended an afternoon diagnostic conference presided over by Major Moehring, chief of the diagnostic radiologic department of Walter Reed at that time. There were also a few periods during which small groups of us were introduced to the film reading sessions and the fluoroscopic procedures at Walter Reed. These periods were interesting and informal, and in fact recreational in character compared with the formal, rapid fire lectures of Colonel de Lorimier. His material was so beautifully organized and presented in such clear, definite form, that one could not help being interested; certainly we had no choice but to register interest and to pay strict attention!

About the first ten days were devoted to X-ray engineering physics. In these lectures and demonstrations a Sgt. Herbert E. Fox participated prominently. He was young and enthusiastic and his knowledge of electricity impressed us. Recalling now, almost eighteen years later, how all of us—and most of us had been out practicing medicine for a number of years—hung on the words of a young sergeant and followed his blackboard calculations and diagrams, with the avidity of a high school physics class —I am impressed with the adaptability of the human race. There was a certain grim determination in everyone to learn as much about those X-ray generators as possible; and time was short. The subject matter reviewed basic principles of electricity, definitions, circuits, transformers, motors, etc. The concept of an auto transformer was new to most of us; comprehension of this device came rather slowly but we went on to reproduce the circuit drawings in satisfactory form. Before too long we had a working knowledge of basic X-ray physics.

Early in the course a long list of subjects, most of which were disease entities, was posted on the bulletin board and we were advised to select one for a research project. This was an aside, although an integral part of the course. Preparation consisted mainly of a review of the literature and other pertinent information all of which had to be

boiled down and described on a 6 inch x 8 inch card. Late in the course there were evening sessions at which we presented these "contributions." About ten were dealt with per hour. But it was a worthwhile effort, and these cards went into the files of the department. There were a couple of short sessions dealing with the foreign body localizer; the one that mounted on the Picker field unit. The use of this device proved easy to learn, else there would have been a loss of some precious time. It turned out that these bi-plane antiseptic (colored) daubing devices were not of real practical value in the field. I recall one session of about two hours on the Sweet localizer. Lt. John Hannon demonstrated this instrument and as usual made a commendable effort. His ability to lecture and explain interestingly and concisely was developed to a high degree. The Sweet localizer used in the lecture was the only one I saw for another two years and it must be admitted that I had forgotten everything but its name and what it was used for. Fortunately I was near a man who had had a considerable experience with the instrument when the occasion for its use arose.

After about the tenth day of the course, Colonel de Lorimier spent about four full days of lectures on the skeletal system. A reflector type machine was set well back in the lecture room which he controlled with a switch and the film projections were considerably magnified. He covered everything from development anomalies to melorheostosis. He went on from this to diseases of the chest; some of the lectures on chest were given by Major Moehring. The head was dealt with by the Colonel. The digestive tract was covered in some general lectures, and then if I recall correctly we were divided into small groups of eight or ten and tutored by members of the staff. The urinary tract was covered in a series of about six lectures. The teaching films were, of course, very good material, and I am sure there were examples of almost all of the known entities.

Part of a day was spent in the radiation therapy section at Walter Reed. Major Friedman was the chief, and in addition to showing us something of the workings of the therapy department he delivered several lectures on the theory of radiation therapy. This was truly new material to most of us.

Altogether the course was a real challenge, at its conclusion most of us left the school with feelings that were a mixture of relief and regret; everyone felt that the month had been one of the most enlightening and stimulating of his life. Many lasting friendships began there. It seems far beyond a reasonable doubt that anyone left without a sincere appreciation and a real admiration for Colonel de Lorimier and his staff. They were making a contribution to the war effort that in our minds ranged well above and beyond the ordinary concept of "line of duty."

For the next nineteen months of field duty with a semi-mobile evacuation hospital I benefited very greatly from what was taught at the school at Walter Reed, and after another interval it was my good fortune to be assigned as a student to the school in Memphis, Tenn., where it had been moved from Washington, D.C. in early 1943. This was a tremendous experience. The course had been lengthened to twelve weeks; it was near the end of the war, and there were only thirteen of us as students. Colonel de Lorimier was commanding officer, and though his staff had been reduced somewhat in size, the teaching procedures had, if possible, been improved. Colonel de Lorimier was somewhat more relaxed, as we all were with the end of the war in sight, but no time was wasted. We covered the same material as was dealt with some two and one-half years before, but in more detail and in more informal manner, probably because of the small size of the class. On a couple of occasions we had evening dinner parties at the Union Club and at these affairs the Colonel and the charming Mrs. de Lorimier participated with as much enthusiasm as the youngest lieutenant there, and in this group there were several really young men who had just completed internships. This course was practically their first assignment in the Army and they admitted to being lucky. Just how lucky they were was more fully appreciated by some of us who were older and had seen some foreign service. Interestingly enough, I know of three other men in this class of thirteen who went on after completion of army service to become radiologists.

At Memphis Col. de Lorimier made use of an orthopedic surgical group for evening conferences on bone lesions. These civilian surgeons were very able men, and contributed a great deal to our knowledge. Dr. Whiteleather of Memphis met with us a number of times on Saturdays, and his lectures and demonstrations on chest diagnostic problems were of excellent quality. Once or twice a week we attended a C.P.C. at one of the civilian hospitals in Memphis, the John Gaston, I believe, and these meetings were profitable.

It is my opinion, and many men have shared it with me, that the schools in medical subjects which the Army developed during the war were tremendous. The top flight physicians, army and civilian, who ran these schools and taught the subject matter made a very great contribution, but the greatest of them all in the opinion of everyone who attended the Army's "Basic School of Roentgenology" was our own Col. Alfred A. de Lorimier!

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CHAPTER IV

Equipment and Supply

Colonel Alfred A. de Lorimier, MC

HISTORICAL NOTE

General Considerations

In August 1959, in response to a request for information concerning X-ray equipment in World War I, Dr. Fred A. Coe [1] wrote that when the United States entered the war, the hot filament Coolidge tube, which had been introduced in 1913, had come into general use in both military and civilian hospitals (*1*). The interrupterless X-ray unit, equipped with a closed coil transformer with a disk or cross arm rectification, had almost completely replaced the induction coil, mercury interrupter, and static machines that had been the only sources of X-ray until the invention of the transformer. The military hospital at Columbus Barracks, Ohio, was equipped with a Wappler unit with a Coolidge tube with crossarms and a synchronous motor. The Army Medical School had a Waite & Bartlett transformer type of X-ray apparatus with disk rectification activated by a rotary converter with a synchronous motor.

At the Army Medical School, Dr. Coe continued—

> The milliamperemeter was hot, reading 0 to 5 and 0 to 50 milliamps. It was mounted above the instrument panel and on more than one occasion the operator, a student doctor, was seen to attempt to turn the button on the milliamperemeter with the high-tension current on. This resulted in near but never complete electrocution. The fluoroscope on this same unit had the Coolidge tube enclosed in a 15 x 15 x 36 inch lead box. The reels for the wires supplying the tube had the unfortunate habit of not functioning properly, allowing the high-tension wire to touch the frame of the table and thus shorting to the hand of the operator and by way of his body and foot to the foot switch. Why did anyone continue in roentgenology!

Obviously, while the equipment available at the beginning of World War I might serve for fixed hospitals, it did not lend itself to military uses overseas. It is remarkable how rapidly better and more useful equipment was devised (*2–7*).

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[1] Dr. Coe, now (1963) a distinguished practicing radiologist, entered World War I as a private in the Medical Corps and ended his service as a lieutenant in the Sanitary Corps. One of his former associates was Dr. (formerly Colonel, MC) Arthur C. Christie, who served as head of the Division of Roentgenology, Office of The Surgeon General, during World War I.

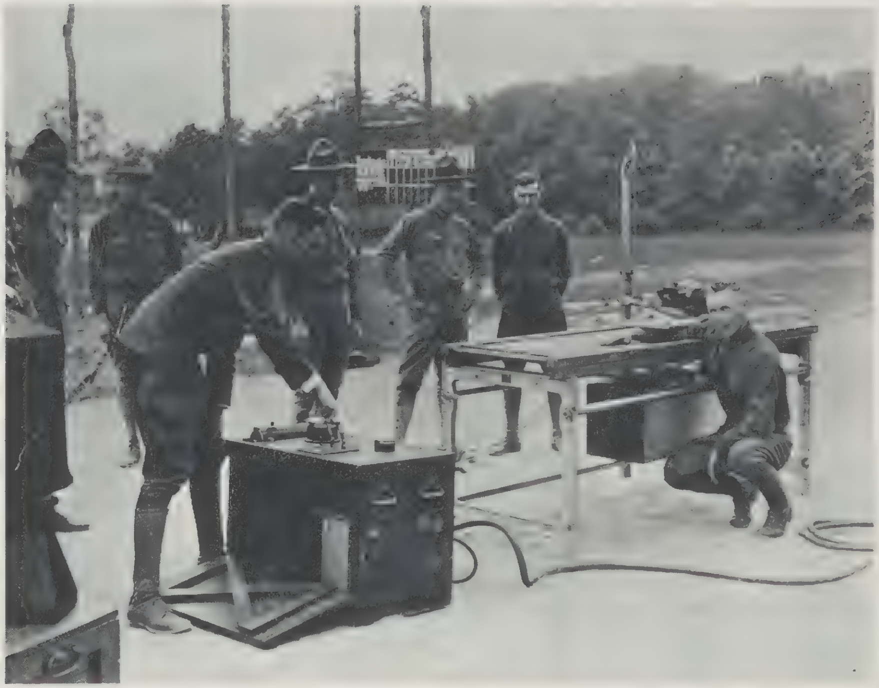

FIGURE 13.—Portable X-ray unit used by Army Medical Department in World War I (2) set up for use. Note side brackets equipped with adjustable locking device used to attain complete rigidity and as tracks to adjust tube container.

X-Ray Table

The large X-ray table which was issued to a number of camps at the beginning of U.S. participation in World War I was unwieldy and unsatisfactory in a number of other ways. In collaboration with the Kelly-Koett (later Keleket) Manufacturing Co., Covington, Ky., Maj. (later Lt. Col.) John S. Shearer, SC, and Maj. (later Col.) George C. Johnston, MC, promptly devised a small, strong substitute which had the added advantage that it could be knocked down (fig. 13). It consisted of two aluminum end frames slotted to receive three tubing members, each 6 ft. long and interchangeable. Each end of these slide members was provided with a screw in the handle that locked them rigidly into place in slots in the side members. On this light, strong, rigid frame could be laid a standard army litter or a specially constructed rectangular frame 6 feet 4 inches by 26 inches, slotted to receive a Bakelite canvas top. This top, which also could be used as a surgical table, was light, flexible, and transparent to X-rays.

Traveling on top of the upper side members was an upright fluoroscopic screen carrier consisting of a tubular barrel in which ran a counterweight attached by cable to the arm of the screen carrier. This device traveled from

end to end of the table and could be made to move synchronously with the tube in its protective box beneath the table.

The whole apparatus could be knocked down for transportation within 3 minutes.

Portable Unit

The portable X-ray unit adopted by the Medical Department in World War I (figs. 13 and 14) was, as Colonel Johnston expressed it, "the product of the inventive genius of Dr. Coolidge," who also invented the tungsten wire Coolidge tube. The Delco engine, which made a portable unit practical, was modified for that purpose by a chance and very fortunate observation made by Maj. (later Col.) Arthur C. Christie, MC, shortly after his appointment as head of the Division of Roentgenology in the Office of The Surgeon General (*1*). When he rode out with his father, a country doctor, to a distant farm, he observed a farmer using a small Delco engine to furnish light for his home and barn and to power several machines, including a milk separator, a churn, and a circular saw. It occurred to Major Christie that this engine, which could easily be carried by two men, would be ideal for a portable X-ray apparatus. Within a few days after he had suggested the possibility to him, Dr. Coolidge reported that while the engine was built to deliver direct current of low voltage, it could be modified by a simple device, a slit ring on the commutator, to supply alternating current at 110 to 118 v., quite suitable for the production of X-rays. Dr. Coolidge was immediately authorized to proceed with the development of a portable X-ray apparatus for military use and within a few months had accomplished all the work necessary for full production.

The air-cooled, finely focused, small-bulb tube which Dr. Coolidge devised for this purpose possessed the unique property of continuously rectifying high-voltage alternating currents, suppressing one phase and utilizing the admitted phase for the production of X-rays.

The portable X-ray unit was self-contained, and its parts were extremely simple: a gas-electric generator, a step-up transformer, a Coolidge filament control, and a Coolidge tube. The introduction of this tube at once eliminated the need for the cumbersome synchronous motors and mechanical rotating rectifying switches previously considered indispensable. The most important point of the new apparatus was that it was so constructed that it rectified its own current. Its total weight was less than a thousand pounds.

In September 1918, information was received that the high-tension soundings on portable transformers had shown a tendency to shift laterally under the strain of transportation. The manufacturers immediately opened all transformers in stock and in depot and blocked the secondary coils in such a way that the shift could no longer occur.

Coolidge tubes, which were used in both portable and bedside X-ray units, were never in short supply because, when the need for them was real-

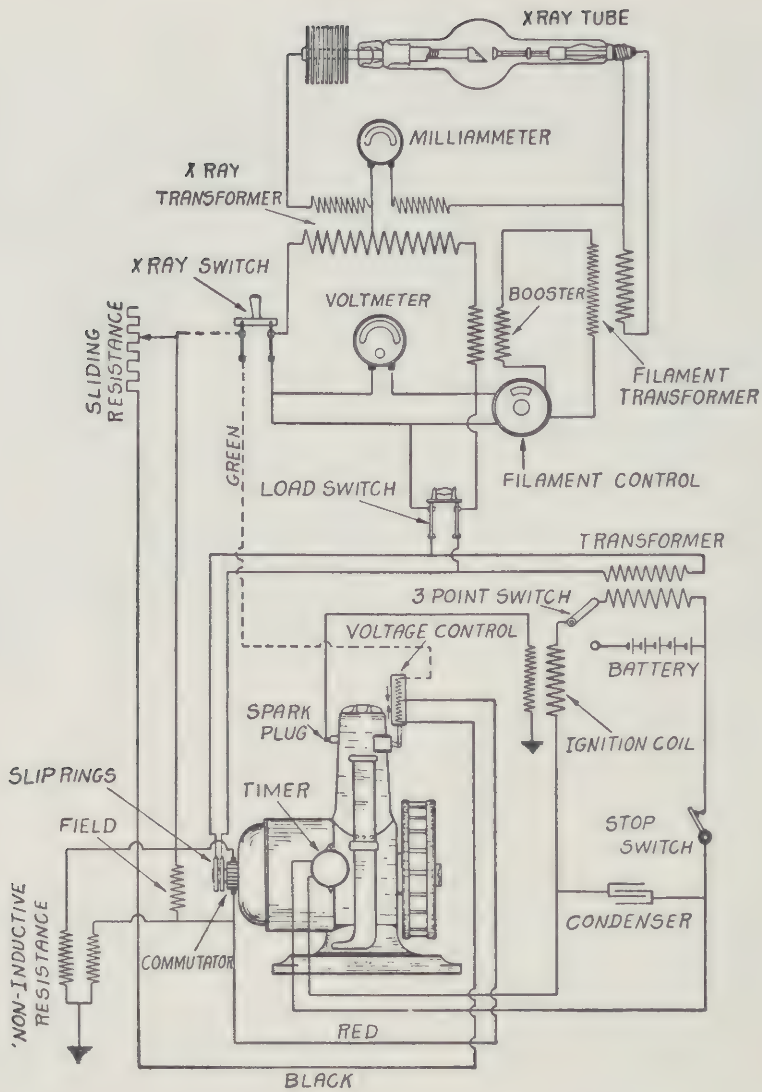

FIGURE 14.—Diagram of wiring for World War I portable X-ray unit. Dotted lines show connections for machines with special control (2).

ized in 1917, the General Electric Co. at once enlarged its facilities for their manufacture. It was possible, in fact, to release large numbers of tubes to our Allies.

Bedside Unit

The bedside X-ray unit used in World War I was devised by Colonel Shearer. A very complete tube-holding device, capable of movement in all

directions and maintenance in any given position, was attached to a small cabinet, 36 inches high and 24 inches wide and mounted on rubber-tired wheels. Within the cabinet was a small high-tension transformer of 50,000 v., and a small inverted rotary converter with a double throw switch could be placed in the base. This apparatus was freely movable. It could be attached to any ordinary socket. If alternating current were supplied, a simple push-button switch, without controls, turned the X-ray on and off. The tube was excited by a current of 5 ma. with 50,000 v. If the current were direct, the switch was thrown to the other side and the inverted rotary converted it into alternating current. In France, Colonel Shearer made a simple modification of the unit to permit its operation from current supplied by the Delco engine of the portable unit. The only factors under control of the operator were time of exposure and distance from tube to plate.

The output of the bedside unit was small and its capacity limited but it rendered remarkably effective service. Some of the machines that had been placed in large hospitals for testing purposes were left there on the entreaties of the staff. Serial examinations in pleurisy and pneumonia and serial studies of fractures were all possible with it. During the influenza epidemic, more than 2,000 radiographs of the chest were made with it at Walter Reed General Hospital, Washington, D.C.

Mobile Unit

A mobile X-ray unit (fig. 15) was devised by Colonel Johnston, by modifying a standard ambulance body, mounted on a ¾-ton chassis, so that it would serve as an X-ray laboratory (*3–7*). Seating arrangements and devices for carrying litters were removed. Across the front of the interior of the vehicle there was built a platform of 2-inch oak plank, upon which was securely bolted a complete Delco gas-electric set with its switchboard. The mounting acted as a spring support for the engine and reduced vibration to a minimum. Dustproof receptacles stowed away in various parts of the body contained the parts of the knockdown X-ray table (p. 46), a tube box with shutters, and a portable darkroom. With their radiators removed, the Coolidge tubes rode safely in canvas hammocks, which served as nests. Water and gasoline were transported in 7½-gal. tanks. A bedside X-ray unit was carried as a spare. Also carried in the body of the trunk was a light-tight canopy with a gas pipe frame, which could be erected in the open, or in any building at hand, for fluoroscopic localization of foreign bodies.

Three Bakelite tabletops were fastened with hinges to the sides of the truck (fig. 15A). One of them, placed on the apparatus in the body of the truck, served as a bed for the officer in charge of the unit. When the other tabletops were dropped to the level of the inside bed and covered with the ambulance curtains, which were longer than usual and were provided with end flies, the housing of the crew was provided for, a matter of considerable importance whenever billeting was the customary method.

FIGURE 15.—Camion used for mobile X-ray operations in World War I (7). A. Exterior of vehicle. Note tabletops, which were used for beds. B. Interior of vehicle, showing equipment.

These mobile units were extensively tested in the United States in the spring and summer of 1918. They were driven over rough roads in record time with highly satisfactory results. The ambulance was not overloaded, the center of gravity was not unduly high, and the load was properly distributed. All apparatus rode safely, and at the end of the trip, it was ready for operation in 4 minutes and 50 seconds against the specified 30 minutes. In late August, when the X-ray apparatus at Camp Meade broke down, a mobile unit, with its portable equipment, took over the total hospital work, averaging 60 to 70 exposures daily for 3 days.

It was a great pity that because of errors of distribution (p. 7), these mobile units did not fulfill their potentialities. Not one of the 17 mobile units that reached France was placed in service before the armistice. Five of them, however, accompanied the Third U.S. Army into Germany, where their usefulness was thoroughly demonstrated.

Similar mobile units were used in the European theater in World War II (p. 405).

Tubes

Although the Coolidge X-ray tube was in general use in 1917, many of the radiologists called into service in World War I were accustomed to using the so-called gas tube, and a considerable number were purchased for that reason, as well as because several firms were manufacturing this tube and the Coolidge tube was being made by only a single firm (*8*). At this time, only the large Coolidge tube was being manufactured, and it had the disadvantage that devices for rectifying the direction of the current must be used with it. Shortly after the United States entered the war, small tubes, capable of rectifying their own current, were developed (p. 47).

Platinum was required in varying amounts in the manufacture of all types of tubes in 1917. A shortage of this element soon made it necessary to modify the tubes furnished, and tungsten, of which there was no shortage, was substituted for it. The quantity of platinum used in all makes of tubes was eventually greatly reduced, it being found that even the platinum wire used, anode and cathode, could be materially reduced and still give satisfactory results. Meantime, all broken X-ray tubes, especially those of the platinum target type, were salvaged and their metal parts turned in to the New York Medical Supply Depot for recovery of the platinum they contained. In March 1918, the manufacture of all platinum target tubes and air-cooled tubes was discontinued and the entire production effort was devoted to tungsten target tubes. Even when priorities had to be obtained for the platinum necessary for X-ray tubes, no material difficulties or undue delays had been experienced.

Current

It was difficult to provide machines sufficiently universal in capacities to adapt to the varieties of electrical current encountered overseas. The large interrupterless type of X-ray machine was not suited to French conditions and only bedside units and modified bedside transformers were useful; this equipment could be operated on practically any type current and used so little of it that it could be attached to any electric outlet.

When the problem of current became evident, the practice was adopted of having all transformers wound for both 110- and 220-v. current. With each unit, an autotransformer was supplied capable of varying alternating currents through a wide range. Synchronous motors employed on the base-hospital type of transformers were 50 cycle but would work on a very considerable range above and below this point. When only direct current was available, inverted rotary converters were provided capable of delivering alternating current from the direct current. Through an unfortunate error, however, the converters first sent overseas were for 220- rather than 110-v. direct current, the type usually encountered.

Problems connected with current seldom arose in the United States.

Plates and Films

Up to 1917, most X-ray work, except for dental X-ray was carried out with glass plates. Developments were in progress, however, for the production of films, and shortly after the United States entered the war, samples submitted by manufacturers were found to be entirely satisfactory for stomach and gallbladder work and for certain other examinations. Films were therefore used in increasing numbers as the war progressed, though early shipments to France consisted mostly of plates. By the end of April 1918 films of all sizes were being shipped.

Workload

No precise figures are available for the roentgenologic workload in World War I. Colonel Johnston recorded, in his administrative history (*3*) that, from February to June 1919, 258,988 patients were admitted to the military hospitals in the United States, 140,205 of whom were examined by X-ray, with the use of 164,061 plates, 60,653 dental films, and 62,252 other films. Fluoroscopic examinations during this same period numbered 24,501. An average of 142 roentgenologists were on duty, each of whom served an average of 364 patients. Of all patients admitted to Army hospitals, 54.1 percent were examined by X-ray; of those thus examined, 15 percent were also examined with the fluoroscope.

According to the official history of the Medical Department in World

War I (*9*), "* * * The proportion of patients X-rayed was 80 percent in the field hospitals for nontransferable cases and 90 to 95 percent in evacuation and mobile hospitals."

It was noted that, to keep up with the work in times of emergency, it was necessary to employ two shifts and to work continuously.

The Johns Hopkins Hospital Unit (Base Hospital No. 18), whose roentgenologic experience covered almost 14 months, found that it could make between 11 and 12 observations per hour, a rate that was sufficient to keep up with, and even ahead of, the demands of the operating surgeons (*10*).

Clinical Considerations

In World War I (*11*), the French attempted to X-ray all surgical patients and almost accomplished their goal by the use of "reinforcing" teams, each provided with its own equipment, which was usually permanently mounted on its own transport, so that reinforcements could be quickly sent to any "point of pressure." The British, during periods of stress, X-rayed about 40 to 50 percent of their casualties.

U.S. Army radiologists used X-ray techniques for the diagnosis and control of fractures and dislocations; for diagnosis of chest wounds and diseases; and, for the first time in military practice, for the early diagnosis of gas gangrene. The recommendation to The Surgeon General of the Committee for the Organization of Schools and Teaching of Roentgenology (*12*) that a chest examination be made on every Army and Navy inductee was not implemented until World War II (p. 110).

During World War I, X-ray found its most extensive use in the localization of foreign bodies. The methods employed included the double-tube shift, the parallel wire methods, the parallax method, the single-shift cross-thread method, the profondometer method, the Hirtz compass with fluoroscopic localization, and the trocar-cannula-harpoon method. Speed and exactitude were the criteria of efficiency, and speed was the more important. At Lt. Col. James T. Case, MC, wrote in the official history (*13*):

> From the surgical standpoint * * * it is more important for the surgeon to be informed of the anatomical situation of a foreign body than of the mathematical distance it lies perpendicularly below a given point of the skin.
>
> * * *. It was exceedingly difficult for those who had not actually participated in forward area surgery under battle conditions to realize how simple, direct, and quick the localizing methods had to be * * *.

When 1st Lt. Charles A. Waters, MC, of the Hopkins Unit returned from overseas, he emphasized the need for the most extreme simplicity in methods of localization (*10*). Major Christie (*6*, *7*) who served in several forward French, British, and Belgian hospitals, under Pierre Duval among others, also emphasized the importance of simplified techniques of localization "en route from the reception room to operating table." He stressed the practical value of fluoroscopic localization of foreign bodies in expediting debridement.

In spite of the advice of these two officers, born of their practical experience, the plan was continued of instructing all student officers in the schools of roentgenology in more complicated techniques. In forward areas overseas, however, it was the practice to discard all methods of localization that required any equipment other than the fluoroscope.

Experience of Base Hospital No. 18.—The clinical experience of the Johns Hopkins Unit, Base Hospital No. 18 (*10*), extended from 1 November 1917 to 25 December 1918 and included 5,084 examinations, of which 960 were negative. All casualties passed through the X-ray department before being sent to the preoperative wards. While numerous examinations, as just indicated, were negative, the presence of multiple foreign bodies was the rule in battle casualties. Foreign bodies in the eye were localized by the Sweet technique. Fractures were common and usually compound. Osteomyelitis and periostitis were infrequent. Three instances of sarcoma of the bone were observed. Tuberculous lesions were extremely uncommon in U.S. Army personnel but relatively common in French civilians, especially among children. Numerous dental radiographs were made, "the teeth of the men in the A.E.F. being none too good."

Two types of bronchopneumonia were observed in the spring, and again in the fall, of 1918, the ordinary type and another variety which was not difficult to diagnose at the end of 48 hours after the onset of the illness but which, before that time, was confusing: It was difficult, and often impossible, to say accurately that any pulmonary involvement was present or, if it was present, whether it was tuberculous. Later, irregular, coalescing infiltrations, more often observed near the hilus than the periphery, might well have been mistaken for an early malignant condition. Section of the lung at autopsy revealed that these areas represented almost true abscess formation. Empyema was infrequent in these cases, probably because the patients did not live long enough to develop it.

THE INTERIM BETWEEN WORLD WARS I AND II [2]

General Considerations

The impetus that World War I had provided for the development of both fixed and field X-ray equipment did not extend to the period immediately following the armistice of November 1918. For one thing, the energies of the Medical Department were then concentrated on caring for the numbers of disabled veterans who constituted from 40 to 60 percent of the patient load in the larger Army hospitals. For another, in the general and fatuous

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[2] Most of the material in the following pages concerning the development of X-ray equipment for military purposes between the World Wars and during World War II was supplied by Maj. (later Col.) Alfred A. de Lorimier, MC, from his intimate personal knowledge of these activities. A great deal of useful information was obtained from the article on the subject which he and Colonel Dauer prepared for publication in 1945 (*14*).

belief that the "war to end wars" had just been fought, the need for further development of X-ray equipment for military use seemed academic.

As time passed, it became the policy to funnel patients with complicated and puzzling conditions to certain hospitals which served, in effect, as hospital centers. In the continental United States, these hospitals included Walter Reed General Hospital; Letterman General Hospital, San Francisco, Calif.; Fitzsimons General Hospital, Denver, Colo., to which patients with tuberculosis were sent; the Army and Navy General Hospital, Hot Springs, Ark., to which patients with joint conditions were sent; William Beaumont General Hospital, El Paso, Tex.; and Fort Sam Houston Hospital, San Antonio, Tex., which, although a station hospital, operated on a scale roughly equivalent to that of a general hospital. Outside the United States, the largest hospitals were Gorgas Hospital in the Panama Canal Zone; Tripler General Hospital in Hawaii; and Sternberg General Hospital in the Philippine Islands.

Conventional commercial X-ray equipment was used in all the larger hospitals, each of which had, in addition, one or more of the portable bedside units developed in World War I (p. 48). The smaller station hospitals depended almost entirely upon this unit, which was designed to operate on alternating current of standard frequency and which contained an X-ray tube that utilized a development new for the time; namely, the thermionic principle of rectification with a radiator for increased efficiency of dissipation of heat into the air. With only slight modification, the same X-ray tube operating principles were applied to the development of an Army portable X-ray unit as opposed to a fixed, stationary unit. It had required only slight modifications (fig. 15) to adapt the operating principles of the X-ray tube used in fixed apparatus to the portable X-ray unit.

It was not until the early 1930's that the need for more efficient military X-ray equipment became evident, after the Manchurian incident in 1931 and the subsequent rising tide of nationalism in Europe.

Development of Field X-Ray Unit

First pilot model.—The first steps in the development of a field X-ray unit were taken by Maj. (later Lt. Col.) John J. Moore, MC, after his assignment, in 1930, as Director of the Department of Roentgenology, Army Medical School. In spite of his manifold teaching duties, he realized that Army X-ray equipment was lagging well behind commercial equipment in at least two respects: It did not incorporate either the shockproofing of high-tension cables or the rayproofing of X-ray tubes, both of which features were incorporated in commercial equipment. After he had discussed these deficiencies with various manufacturers, Major Moore finally persuaded the General Electric X-Ray Corp. to undertake the development of an Army field unit that would be shockproof and rayproof and that would be usable in a theater of operations as well as in smaller station hospitals and other small stationary medical installations in the Zone of Interior.

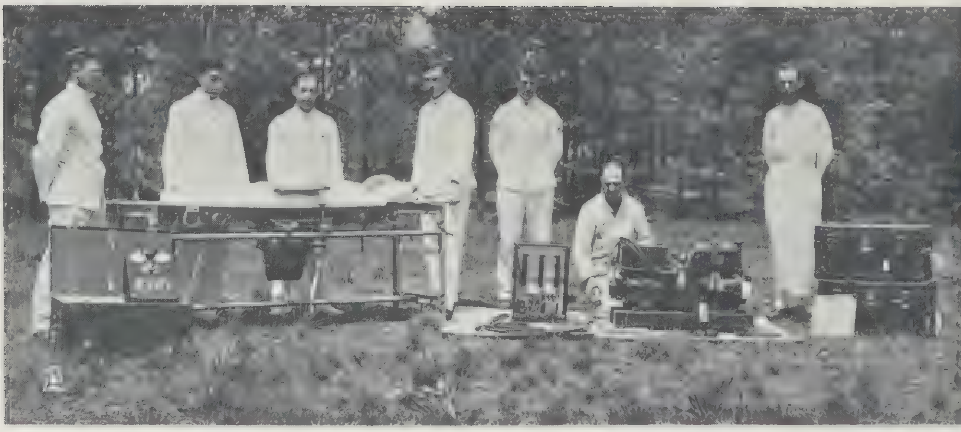

FIGURE 16.—Shockproof, oil-immersed tube for portable X-ray unit devised by General Electric X-Ray Corp. in 1934. A. Unit, set up for operation, is equipped with portable table, fluoroscope, and special stretcher which can be used for foreign body localization without moving patient from litter on which he was originally placed. Picture was furnished by M. Sgt. Lawrence R. Black (Ret.), at right, codesigner with Col. Alfred A. de Lorimier, MC, of localizing equipment used in World War II.

In May 1934, after almost 3 years of effort, a pilot model (fig. 16) was submitted by the General Electric X-Ray Corp. to the Army. The machine was a tribute both to Major Moore's foresight and to the cooperative spirit of the corporation. The approximately $15,000 that it cost was a far more substantial sum in 1934 than it is in 1965. Unfortunately, the model was delivered just before Major Moore's assignment was changed, in accordance with the so-called Manchu regulation, still in effect, which restricts the tour of duty of an officer in metropolitan Washington and nearby Virginia to not more than 4 years at any one time (*15*).

The General Electric pilot model, designed entirely for use in mobile forward medical installations, provided the desired shockproof and rayproof characteristics, but this achievement gave rise to another problem: The currently available field X-ray unit, as well as many conventional commercial units, permitted fairly efficient heat dissipation because both X-ray tubes and high tension leads were exposed to the air. Shockproofing and rayproofing (by the envelopment of the tube in oil and provision of a rayproof shield) reduced heat dissipation considerably, and the inevitable result was chronic, serious, overheating of the X-ray tube. When the factors then in common use (settings of 70–80 kvp. and 3–4 ma.) were utilized, fluoroscopic performance was limited to 10-minute periods. The time limit presented no insuperable problem in fixed military hospitals in which, as in civilian hospitals, intervals between fluoroscopic observations were possible, but it was a grave drawback in a field hospital, in a combat situation, in which large numbers of casualties had to be handled within short periods.

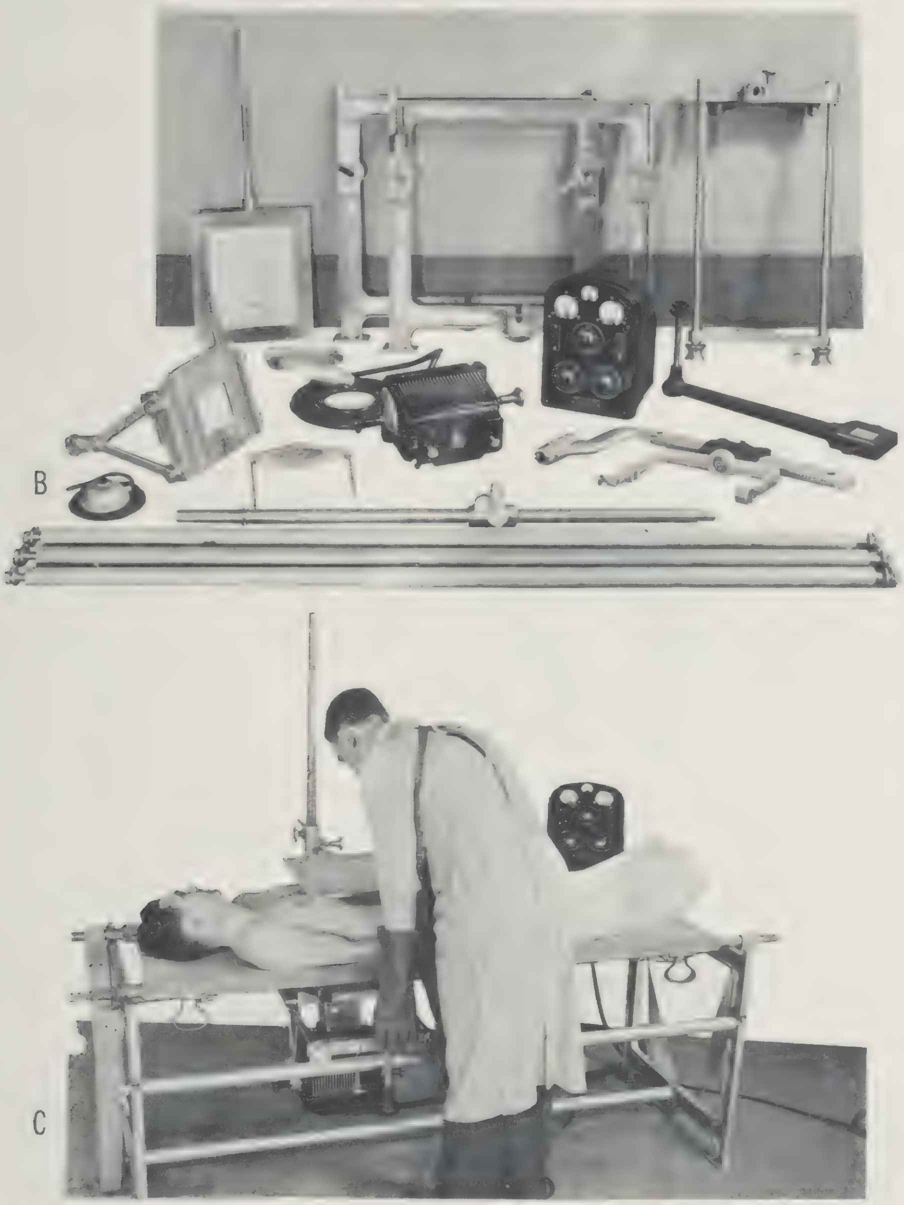

FIGURE 16.—Continued. B. Unit disassembled. C. Unit in use for horizontal fluoroscopy.

FIGURE 16.—Continued. D. Post-World-War-II revision of unit shown in views A–C, which had some use in Korea.

In a rather cumbersome attempt to solve this problem, the pilot model was provided with two tube heads, the idea being to submerge ("dunk") the hot head in a tube of cold water after it had been used for 10 minutes, the second head being used until the first was sufficiently cooled to permit its substitution.

Second pilot model.—Happily, Maj. William W. McCaw, MC, who replaced Major Moore as Director of the Department of Radiology at the Army Medical School and at Walter Reed General Hospital in 1934, shared his predecessor's concern about the deficiencies of military X-ray equipment. His efforts in the design and development of a field unit resulted, in 1936, in the production of a second pilot model by the Kelly-Koett Manufacturing Co. This model was a considerable improvement over the first, but it did not solve

the serious problem of alternating the use of tube heads and dunking the one that had just been used, at 10-minute intervals.

Further developments.—In the middle of 1938, Capt. (later Col.) Alfred A. de Lorimier, MC, succeeded Major McCaw at the Army Medical School and Walter Reed General Hospital. Since he had served as Major Moore's assistant in the early 1930's, he was familiar with the developmental problems that had arisen in connection with the first pilot model of the field unit. He was aware of the interruption of programs inevitably caused by the Manchu regulation (p. 56) and realized the necessity for prompt work in the present model. He was even more aware of the necessity for haste because of the mounting crisis in Europe and because his last assignment had been in the Canal Zone, where he had observed the countless shiploads of scrap metal moving through the Canal on their way to Japan.

Captain de Lorimier's first activity was an evaluation of the existing pilot models, with particular respect to their deficiencies. A shop was set up in the basement of the Army Medical School and X-ray personnel were assigned to construct pilot models of the field unit and also to construct table units and various accessory items.

At this time (1938), it was thought that most roentgenologic activity in forward medical installations would be fluoroscopic, particularly for the localization of foreign bodies. It was also recognized that, in the event of war, movement of troops would be rapid and casualties often heavy, so that it would be manifestly impractical for a roentgenologist and his assistant to interrupt the observation of casualties to remove a tube head, dunk it, and substitute another for it. High priority was therefore attached to the provision of continuous operations at fluoroscopic capacities.

Captain de Lorimier discussed this essential requirement with various manufacturers, whose engineers were uniformly pessimistic as to its possible accomplishment. Comments to this effect were directed from various sources to the Office of The Surgeon General, which in one instance was bluntly informed, that "de Lorimier is crazy." Meantime, Captain de Lorimier and his assistants continued to work with pilot models in the basement of the Army Medical School, making some progress in their objective by the use of small fans to direct air on the anode terminal of the tube head to enhance heat dissipation. When The Surgeon General conveyed to Captain de Lorimier the manufacturers' evaluation of the latter's work and advised him to cease being "impractical," Captain de Lorimier replied that the Army required the features being developed and asked him to be patient.

One point in which manufacturers were naturally interested was the number of tube units which might be purchased ultimately, and several requests were submitted for this information. After careful consideration of possible tactical situations that might develop worldwide, and after what later proved to be very liberal allowances were made for contingencies, a figure of 93,000 units was arrived at. This estimate later proved to be very much too high. The earlier figure, however, was not without logic: The extent of a

possible war was extremely uncertain in 1938, when World War II had not yet begun, and it was still 3 years before the United States was to enter it. Moreover, tube-life in 1938 was much shorter than it was later during the war.

Obsolete specifications.—At about this time, a production difficulty, arising from specifications provided to manufacturers, exploded, with ultimately important results in the development of military X-ray equipment:

Early in 1938, the Army had ordered a commercial high milliamperage X-ray machine unit, a table unit, and a cassette changer from the Standard X-Ray Co., Inc., of Chicago, based upon Medical Department Tentative Specifications, NYGD (New York General Depot) 415 & 416, dated 23 February 1938. In the fall of 1938, when the company attempted to make delivery to Letterman General Hospital, Lt. Col. L. R. Moore, MC, in charge of the Department of Radiology there, rejected the equipment as obsolete. Two naval radiologists, Cdr. Walter A. Fort, MC, USN, and Cdr. Frederick W. Muller, MC, USN, inspected the equipment and concurred in Colonel Moore's finding, as did the Supply Division, Office of The Surgeon General, after a detailed investigation.

The Standard X-Ray Co., Inc., as might have been expected, reacted rather violently, and on 10 December 1938, the company lawyer sent to the Honorable Louis Johnson, then Assistant Secretary of War, a communication which read, in part, as follows:

> We will not sit idly by while this discrimination takes place, to some extent due to our refusal to join with a price fixing combination under a plan to split government business equally among those who would participate in this scheme.
>
> I desire to present to you evidence of the unjust and unfair treatment of the Standard X-Ray Co. by Colonel Moore, and to show by evidence that the equipment * * * is wholly in conformity with the specifications and has operated satisfactorily. It is the intention of the Standard X-Ray Co. to pursue its complaint determinedly and I request that a hearing be had by the War Department in conformity with the complaint of the Standard X-Ray Co. as set forth in this letter.

At a conference between representatives of the company and the Army on 29 and 30 December 1938, certain important facts emerged:

1. Certain minor deficiencies and discrepancies were apparent in the equipment, arising from the interpretation of the intent, if not of the actual wording, of the specifications. The company, for example, granted that line voltage adjustments had to be accomplished after removal of the control panel and changing of wire connections rather than by utilization of a hand-operated switch on the front of the panel, as was desired. The Army also objected to the use of a leaded glass bowl about the X-ray tube for rayproofing.

2. When the company engineer, Mr. C. B. Turner, was asked whether he considered these and other features of the equipment of modern (that is, 1938) design, he replied, "No, I don't think that is modern equipment and I don't think your specifications are modern in any way."

3. During a recess in the hearing, Captain de Lorimier, who was representing Colonel Moore, radiologist at Letterman General Hospital, was asked by Col. R. D. Harden, MC, Chief, Supply Division, Office of The Surgeon

General, whether there was any basis for Mr. Turner's remarks. His reply was, "Yes, unfortunately, our specifications are at least eight years obsolete."

Establishment of liaison with manufacturers.—The facts brought out at the hearing just outlined laid the groundwork for the constructive activities that followed.

All through 1938, planning and experimentation continued in the basement workshop at the Army Medical School, and at an increasingly feverish rate as world conditions worsened. Numerous experimental models of a field X-ray unit were constructed, but all were limited by the existing state of the art and by the known limitations of manufacturing capabilities. During the later months of the year, representatives of several manufacturers visited the Army Medical School, more or less casually but not infrequently with a notably supercilious attitude, based on the belief—often stated frankly—that company engineers could do a better job.

Gradually, however, this attitude underwent a change, as it became apparent that the devoted group at the Army Medical School was working earnestly and with scrupulous attention to the necessary requirements for a field X-ray unit. More serious and more meaningful discussions with manufacturers then began to take place.

After the difficulties with the equipment made by the Standard X-Ray Co., Inc., according to Army specifications, the Director of the Department of Radiology, Army Medical School, became more clearly an ex officio consultant to The Surgeon General in radiologic matters, including the preparation of specifications. He also traveled to various factories manufacturing X-ray equipment, in order to become thoroughly conversant with commercial developments and capacities. Among his trips were those to the following firms:

1. The (then) Long Island X-Ray Co., New York City.
2. The Machlett Laboratories, Inc., Springdale, Conn.
3. The Picker X-Ray Corp., Cleveland, Ohio, where he became acquainted with John Victoreen and his work in the development of ionization measuring devices.
4. The Kelly-Koett Manufacturing Co., Covington, Ky.
5. The General Electric X-Ray Corp., the Standard X-Ray Co., Inc., the Mattern Co., and H. G. Fischer and Co., all of Chicago.
6. The Buck X-Ograph Co., St. Louis, Mo., which manufactured accessory X-ray equipment.

These visits were of great value in establishing direct contact with leading manufacturers of X-ray equipment. They permitted the discussion of the features essential in military equipment and also an understanding of the manufacturing problems involved. Out of them came a firsthand acquaintance with the manufacturers and also a liberal education in the preparation of specifications for X-ray equipment for the use of the Supply Division, Office of The Surgeon General.

With clear recollection of the difficulties that had arisen over the specifications used by the Standard X-Ray Co. in 1938, an attempt was made to write

into future specifications the most desirable features found in the products of all the manufacturers visited, so that the best and most modern equipment could be provided for the U.S. Army. Attention was also paid to the records of the Supply Division, Office of The Surgeon General, which contained numerous letters from hospitals and posts all over the country about deficiencies and inadequacies of various types of equipment supplied by various manufacturers. Correspondence with physicists and radiologists all over the country revealed that the provision of specifications so complete as to cover every possible desirable feature was almost impossible. It was therefore considered entirely justifiable to draw up specifications that would be sufficiently comprehensive to allow contracting officers adequate grounds for rejection of equipment when this would be necessary. Each purchase specification covered 10 to 12 pages of highly detailed requirements. The overcomprehensiveness of these specifications soon became evident to manufacturers, and rumblings of complaints and suggestions that the requirements were impractical again began to reach the ears of The Surgeon General.

The solution of the problem.—The basic limitation of the X-ray tube itself, overheating, continued to hamper the development of the field X-ray unit at the Army Medical School. Meantime, the Picker X-Ray Corp. had also been working on the problem, at first independently and, after September 1939, in cooperation with the Army. By this time World War II had erupted, and it was essential that usable and efficient equipment be developed as rapidly as possible.

The problem of prolonged fluoroscopy was finally solved by Mr. E. R. Goldfield of the Picker X-Ray Corp.[3] He not only utilized an outer shield, within which air cooling was accomplished by means of a small fan, but also included an oil-impeller within the main housing of the X-ray tube to provide for continuous oil circulation (figs. 17 and 18). With provision for adequate dissipation of heat, other manufacturers soon realized that a tube capable of continuous operation at fluoroscopic capacities was both possible and desirable. Numerous problems remained to be solved, but with the difficulties connected with the tube overcome, development continued rapidly, and when the United States entered World War II, it had an efficient, practical field X-ray unit already in production (figs. 19 and 20).

CRITERIA OF EQUIPMENT

The concept of roentgenologic service underwent an evolution between the end of World War I and the end of World War II, the most notable changes occurring during the early months of the Second World War:

1. The demands for roentgenography were much greater than had been anticipated, either by radiologic personnel in the Army or by manufacturers

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[3] Details of the work of the Picker X-Ray Corp. in the development of the airflow tube and later phases of the development of other parts of the field unit appear in the communication by Mr. Goldfield (appendix A, p. 923) in which the story is told from the point of view of the company.

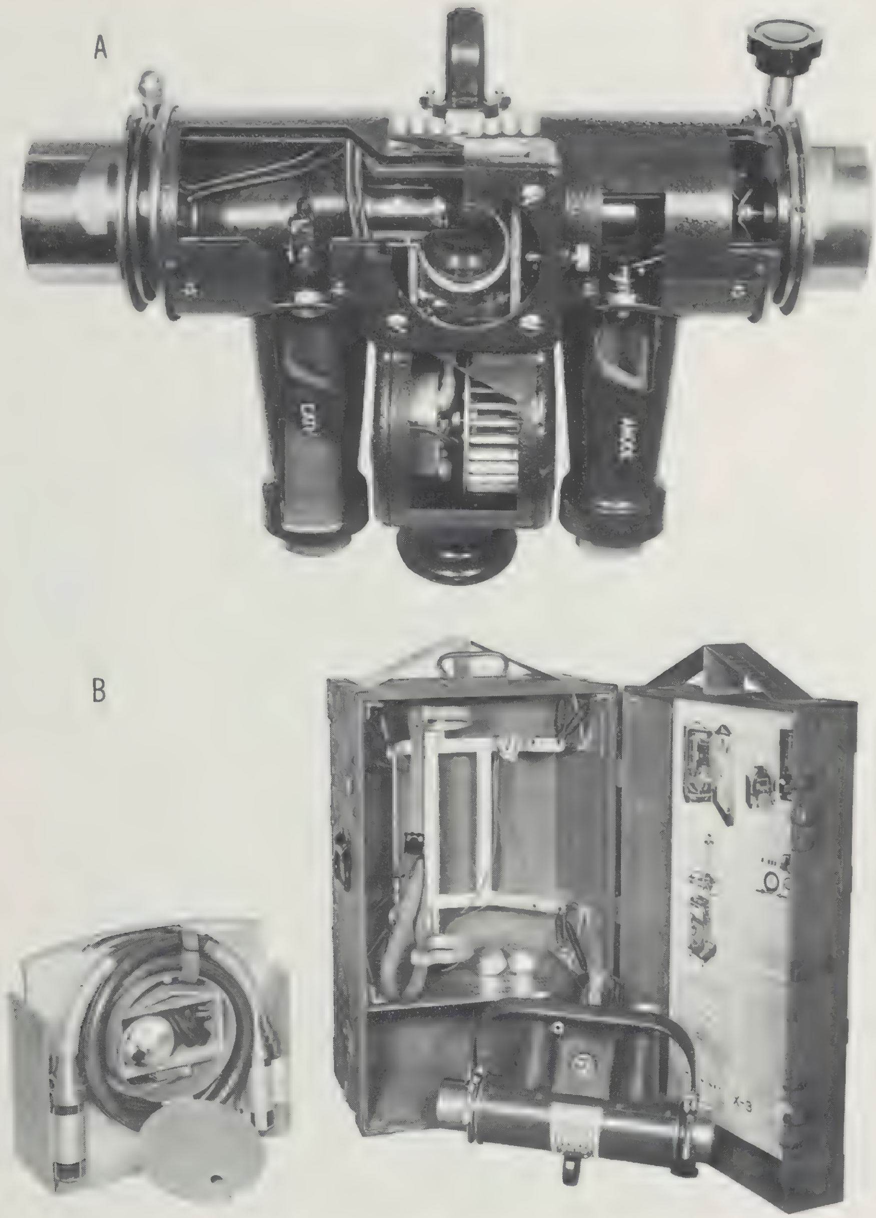

FIGURE 17.—Army airflow (oil-impeller) X-ray tube with continuous rating of 80 kv., 5 ma. A. View of tube with housing cut away. B. Transportation chest open to show spring suspension type of cradle that supported tube unit and reduced damage from impacts. Note exceptionally long terminals on shockproof cables.

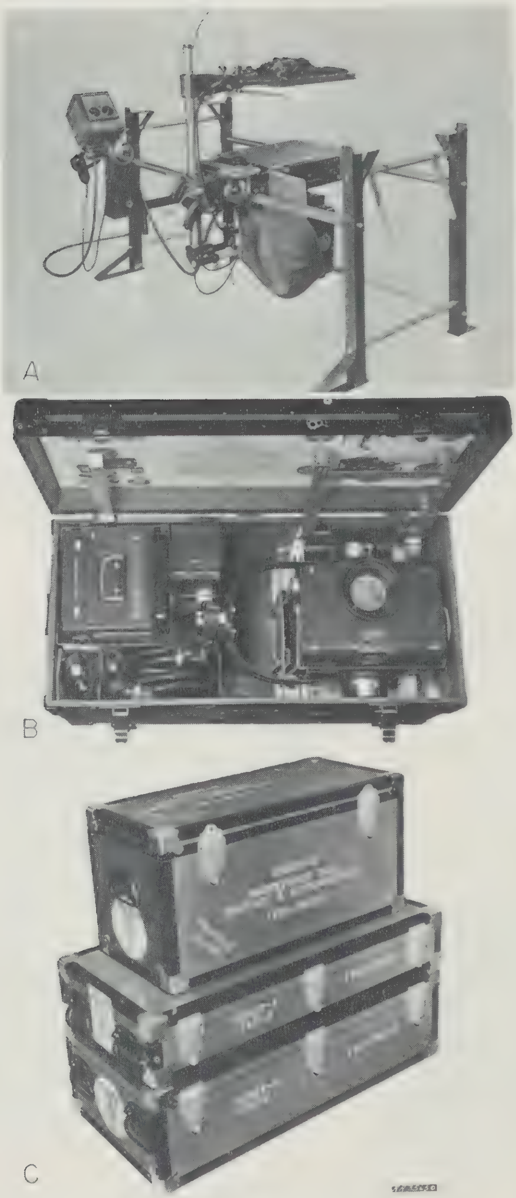

FIGURE 18.—Light airflow Army unit. A. Table and control. Note lead shielding to protect fluoroscopist's legs and feet. B. Unit with control and cables in case for transportation. C. Complete unit packed for transportation.

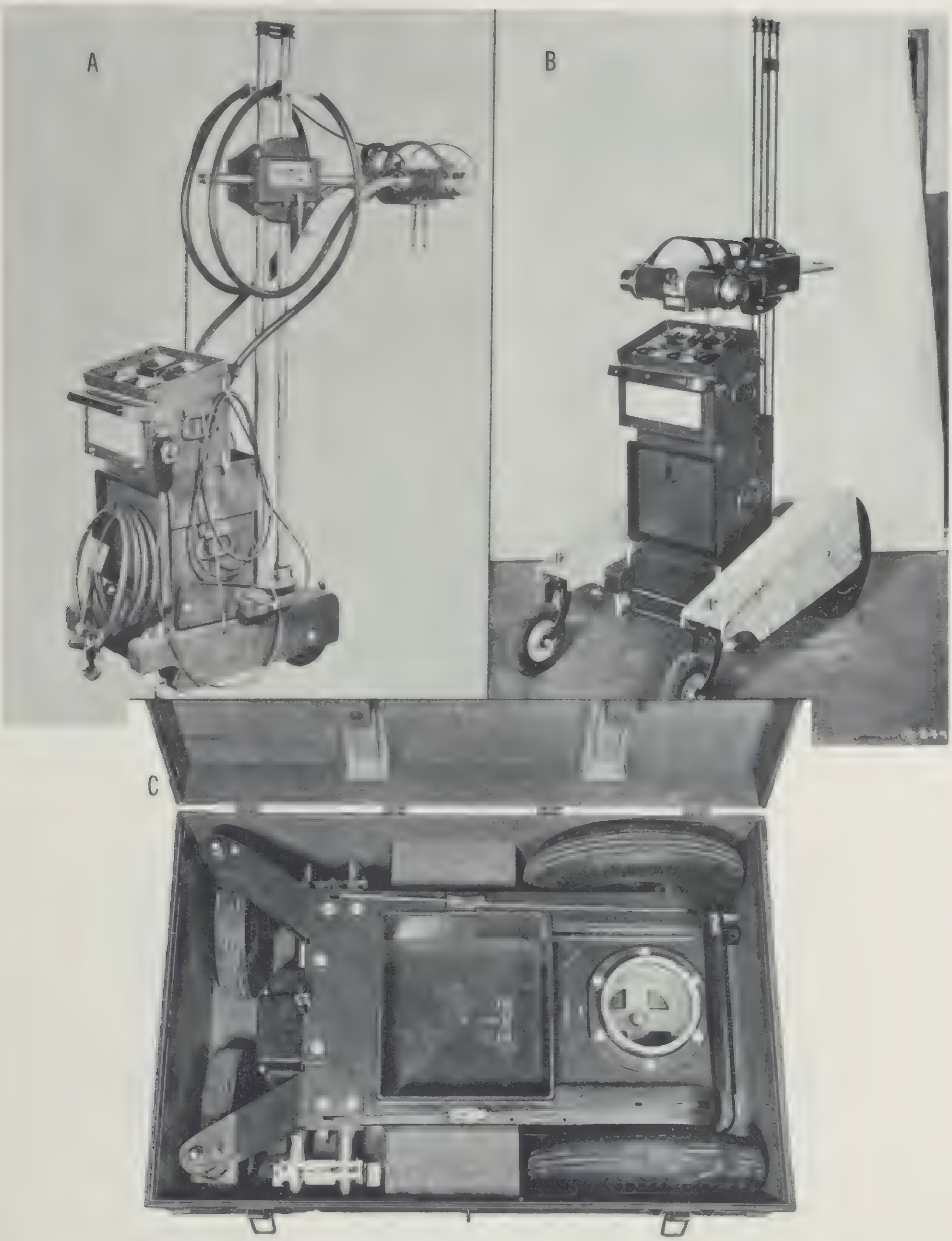

FIGURE 19.—Picker portable basic field X-ray unit. A. Early model, with small wheels. B. Later model, with larger wheels. C. Later model packed for transportation (see fig. 18).

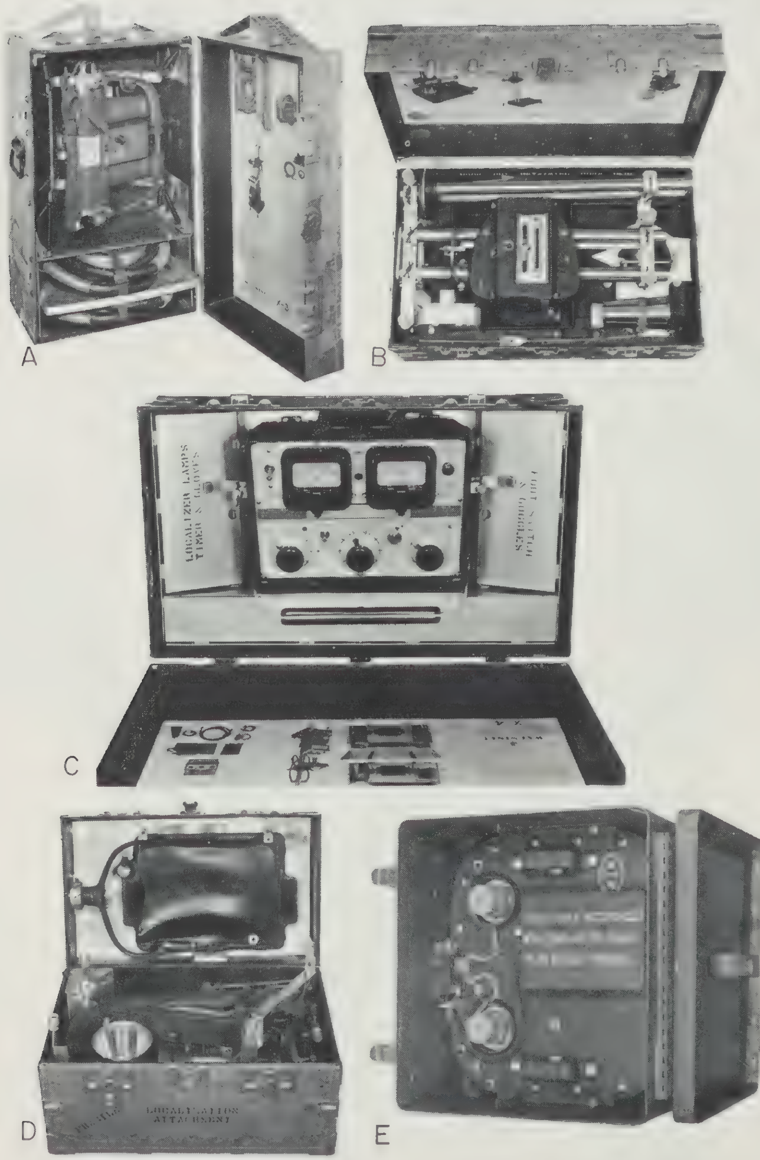

FIGURE 20.—Picker basic field unit packed for transportation. A. Tube unit and high-tension cables. Note spring suspension provided for tube, and device to keep chest upright. B. Support mechanism. C. Controls of unit, with compartments for accessories. D. Localization and fluoroscopic attachments. E. Transformer component.

of equipment and films. Roentgenologic examinations were required before induction of all personnel into the service and were also required at the conclusion of service. They were also extensively employed in forward installations, in which it had been thought only roentgenoscopy would be required, and serial examinations were numerous.

2. It had been believed before the war, as just intimated, that roentgenoscopy would be the most important phase of X-ray service and that provision should be made for a rapid method of foreign body localization (*16*). As a matter of fact, roentgenography was used far more often than roentgenoscopy (fluoroscopy), and the elaborate apparatus devised for the localization of foreign bodies (p. 72) was scarcely used at all.

3. It was also believed that some provision should be made for X-ray therapy, at least in the management of infections and dermatoses. The provision of radiation therapy in a theater of operations represented a considerable departure from established concepts, but its desirability had been established by studies conducted by Kelly of Omaha, Nebr. (*17*), and others. The antibiotics had not yet been introduced, and it was thought that radiation therapy might be useful in the control of cellulitis, abscesses, peritonitis, and gas gangrene. With the introduction of the sulfonamides and penicillin, this modality became unnecessary in infections, the incidence of which was very much smaller than had been anticipated.

4. Before World War II, radiologists with World War I experience believed that for field service it would be necessary to provide only for horizontal roentgenoscopy and for foreign body localization. The group working at the Army Medical School did not accept this concept. It was their belief that Army equipment should be both versatile and adaptable, usable in time of peace and in time of war, and also usable in fixed and in field locations.

The equipment envisaged by the group at the Army Medical School embodied the following requirements:

1. It would permit roentgenoscopy with the casualty lying on the litter on which he had been placed when he was removed from the combat area and could be accomplished in the recumbent, the sitting, or the upright position (fig. 16C).

2. It would permit roentgenography in fixed hospitals as well as in mobile hospitals.

3. It was considered important that every item of equipment be serviceable in any echelon of medical care, that the handling of this equipment should be largely reflex, and that it should not be necessary for the operator to make a detailed study of the operation of the control before using the equipment. It was considered particularly important that equipment utilized in forward echelons should be familiar to personnel serving in rear echelons, who might suddenly be moved to the front. Transfer of personnel to other areas could thus be accomplished expeditiously, with a minimum period of time required for adjustment to a fluid combat situation.

4. These criteria implied the provision of a single type of equipment to serve the needs of all hospital installations and also implied a high degree of interchangeability of basic units to meet the changing requirements of fluid situations rather than dependence upon special equipment for each function.

5. The equipment should be designed to permit easy assembly and disassembly. It should be simple to operate and maintain. For military reasons it should be both rugged and dependable. Small detachable parts should be avoided. For convenience, each item should be designed as two or more components. Each component should be packed separately, with bulk and weight so limited that the item could be carried by two men. Two hundred pounds was set as the goal for any single component (packed).

The X-ray machine was ordinarily utilized in connection with the field table (fig. 20A). A mobile chassis was later designed, to permit the use of the unit for ward work (fig. 19). The first such chassis was equipped with small caster-type wheels which proved unsatisfactory in theaters of operations (pp. 261 and 380) in which the machine had to be moved over rough ground and used in improvised buildings. Later, the chassis was modified and equipped with large pneumatic rubber tires.

Various adaptations of the field unit were worked out to allow for different uses and different positionings. Much credit for the construction of the preliminary models is due to T. Sgt. Lawrence F. Black and S. Sgts. Roy Day and Herbert Fox, of the Army Medical School. Among these uses and positions were the following:

1. Horizontal roentgenography with tube above table (fig. 21).
2. Horizontal roentgenoscopy, with the tube unit adapted to an arm support beneath the patient (fig. 22A).
3. Roentgenoscopy in sitting position.
4. Horizontal roentgenography with focal film distances up to 6 feet. The patient is positioned on a litter at floor level (fig. 22B).
5. Vertical roentgenography also using long focal film distances.
6. Bedside roentgenography, with utilization of mobile arrangement of X-ray machine.

Production Problems

All manufacturers were invited to cooperate with the Army in the development of both basic and accessory equipment. Some manifested particular interest in one item, some in another. Contract awards were predicated upon special facilities and competitive bids. It was advantageous to have a single manufacturer obtain contracts for the construction of all units of one particular type. The arrangement provided definite assurance of easy and complete interchangeability of parts. At the same time, it was practical and desirable that the greatest possible number of qualified manufacturers be engaged in the overall procurement program, not only because this policy was equitable but also because it insured expeditious and continuous supplies of all necessary items.

FIGURE 21.—Roentgenography with field table of Picker unit.

The manufacturers cooperated enthusiastically, and practically all production schedules were completed on time (fig. 23). The utmost engineering skill was exercised, and many ingenious innovations were incorporated into the various items finally produced. Unfortunately, time did not permit the testing of pilot models under actual or field conditions, but by informal arrangement, many of the "bugs" that plague all new equipment were detected and eliminated during the early stages of construction. In addition, a considerable amount of valuable constructive criticism permitted corrections of defects that became apparent as the first few units were put into operation (p. 93).

One of the chief production difficulties concerned the approximate quantities of each item that would be required. The precise information would have been of great value to the manufacturers, but the best that could be provided was estimates based on probabilities.

During the early phases of development of equipment, all the attention was devoted to design and to practical consideration. At this time, materials of all sorts were available. Aluminum and lightweight alloys were used extensively, and weights could be held to a minimum. Almost as soon as large-scale production started, however, the program was plagued with shortages of material, and the Medical Department was no longer allocated alumi-

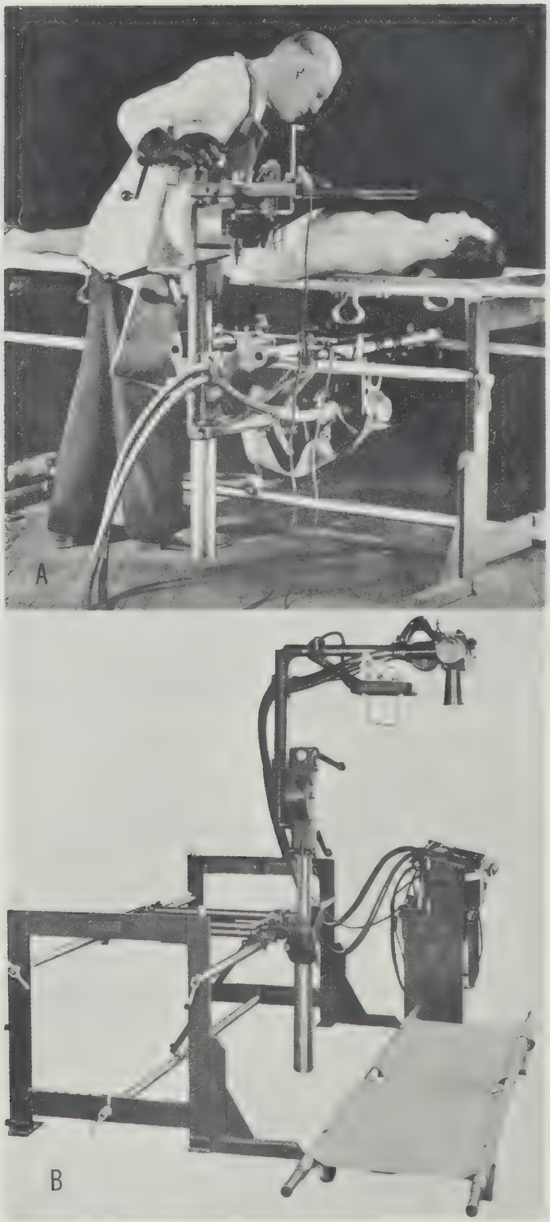

FIGURE 22.—Various positions for roentgenoscopy (*16*). A. Horizontal roentgenoscopy. B. Positioning on litter on floor for 6-foot radiography.

FIGURE 23.—Scenes at Picker X-Ray Corp. factory during World War II. A. Production of equipment. B. Basic field equipment ready for packing.

num. At the height of the production schedule, the supply of many important items became critical, particularly electrical components, including meters, special switches and relays, power cables, and wiring.

When the lightweight materials originally used were no longer available, retooling was frequently necessary, and in some instances, changes of design were required. Equally disturbing was the increase in weights; several items which previously had weighed below the desirable 200-pound limit were increased in weight by 25 or 30 percent.

Mr. Goldfield of the Picker X-Ray Corp. promptly recognized the seriousness of this problem and, without any direct motivation from the Army,

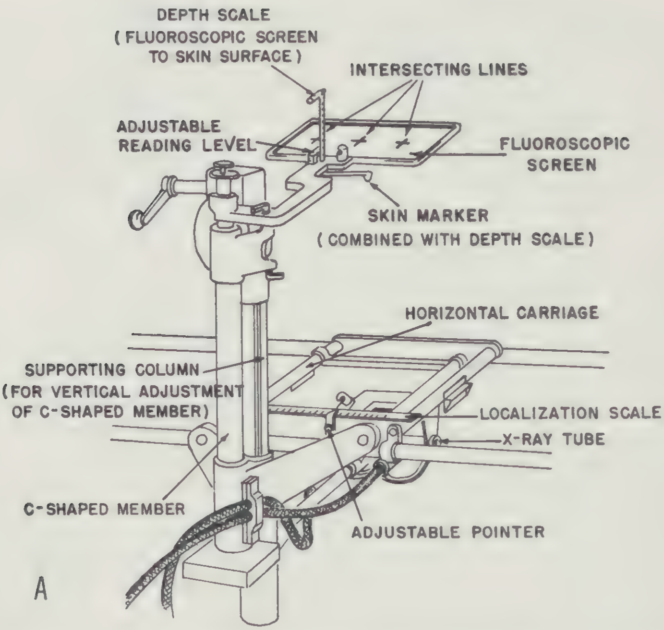

FIGURE 24.—Diagram of equipment for foreign body localization (*16*). A. Modification of X-ray table.

independently designed and constructed the lightweight combination machine and table unit that came to be known as the airflow unit (U.S. Army item 9621500). This unit (fig. 18) proved a highly practical piece of equipment in forward hospitals and mobile installations.

EQUIPMENT FOR LOCALIZATION OF FOREIGN BODIES

Basic Apparatus

The methods of foreign body localization used in World War I, while basically sound, were cumbersome and time consuming and were unlikely to be practical in the type of rapid action which was expected to characterize World War II. Major de Lorimier and his assistants devoted considerable time and attention to this problem, and eventually the design of the table unit was modified to incorporate equipment for foreign body localization (fig. 24). The essential features of the modification were that crosslines were etched into the fluoroscopic screen and a depth scale was provided on its arm support. The work was done with the special cooperation of the Westinghouse X-Ray Co.

With the modification of the field table unit devised by Major de Lorimier and his assistants, it was possible, by fluoroscopy, to locate the

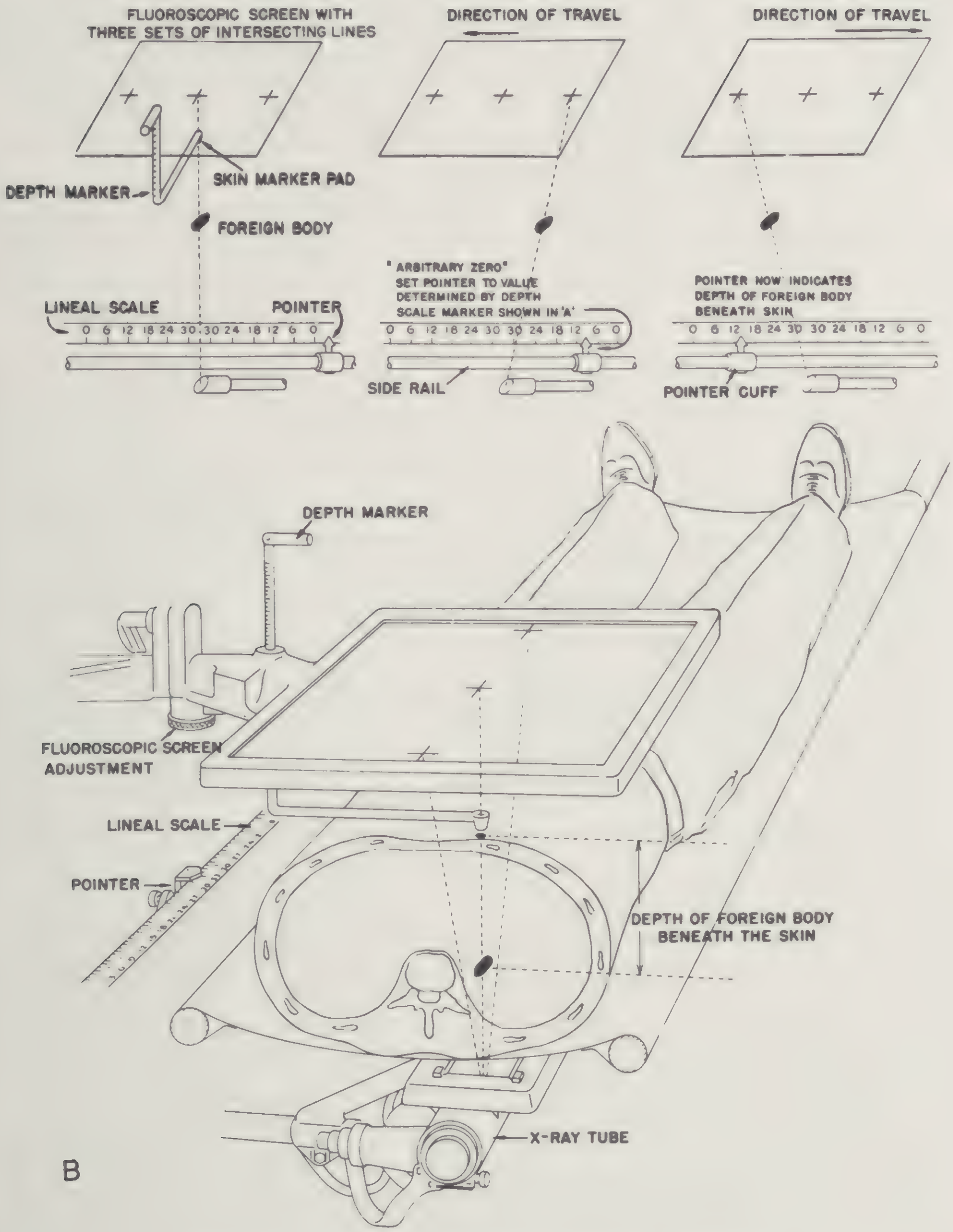

FIGURE 24.—Continued. B. Basic localization procedure.

foreign body and to determine its distance beneath the skin by simple triangulation (*16*). This method, however, became highly inaccurate once the patient's position was changed; then the vertical relation between the skin marking and the foreign body also changed. The change was of no great significance when the object was sizable and near the skin surface. When it was small and deep, further guidance was necessary.

Another source of error arose from the necessity of changing X-ray tubes from time to time, with resulting variations in the position of the focal spot in respect to the fluoroscopic screen. It would have been impractical to adjust the fluoroscopic screen or each tube every time a tube was changed, and a method was devised to overcome this potential error by determining its extent and compensating for it.

Further trials of the new apparatus disclosed other possible sources of error in addition to those already mentioned. During hot and humid weather, the Bakelite support of the fluoroscopic screen sometimes buckled and the screen itself sometimes developed surface corrugations. Parallax had to be considered, since one examiner might make his alinements by perpendicular viewing while another might make them more tangentially. Thought also was given to the possibility of the difference in effect of penumbra, with consideration of the effective focal spot dimensions concerned with the two alinements.

Errors due to these various factors were relatively small, amounting to not more than 5 mm. in the depth calculations, but it seemed important, nonetheless, to attempt to compensate for them if only to prevent operators from becoming careless in technical procedures, in the knowledge that the equipment itself was not capable of accuracy. Accordingly, an adjustable reading level for the depth scale marker was incorporated in the apparatus (fig. 24B).

Although careful testing and adjustment of the apparatus were carried out at the factories before it was shipped, instructions were given in the Army manual for radiologists (TM 8–275) to make a preliminary test of adjustment before the equipment was used. Testing was accomplished by a simple procedure involving the use of a depth phantom. The preliminary testing had two purposes: It oriented the radiologist in the procedure, and it permitted further compensation for variables that might have arisen in shipment or with changes of climate.

After he had become acquainted with the technique, the radiologist could localize a foreign body in 30 to 45 seconds, with minimal exposure of the patient. At most, exposure did not exceed 140 ma.-sec. The most unfavorable conditions were encountered when the shortest focal skin distance was used (about 10 inches, allowing for a 4-inch sag of the litter), but, even then, the exposure of the patient did not exceed 15 r.

Biplane roentgenoscopy.—Biplane roentgenoscopy was advocated by some roentgenologists, and some surgeons expressed the desire for an indication of foreign bodies in two planes. This technique, however, was not considered practical with the unit developed for several reasons:

1. It would have required either the use of two tubes and two fluoroscopic screens or readjustments of one tube or screens. Either arrangement would have been costly in terms of weight, money, and time.

2. Small foreign bodies could not be adequately visualized through the thicker portions of the body, such as the chest and trunk.

3. If many fragments were present, double markings would be likely to lead to confusion.

4. Biplane roentgenoscopy would have required double or more than double the radiation exposure of the patient and a concurrent increase in the secondary exposure of the operator.

Biplane Marker

The biplane marker developed to minimize fluoroscopic exposure of the patient and the secondary exposure of the operator was an accessory item of the table X-ray unit, not an integral component.[4] Its virtue was that it provided information without additional roentgenoscopic visualization.

The biplane marker consisted of a horizontal leveling arm with an adjustable marker that moved on a vertical supporting arm. Centimeter gradations were etched on the leveling arm to provide for positioning the marker to the depth level indicated by the basic localizing procedure. If the horizontal arm rested upon a level higher than the level at which the object had been localized, the marker could first be used to measure the distance between these two levels; this difference, when added to the depth calculation value, showed the proper level for positioning the spotter of the marker. This second marking (that is, the marking in the vertical plane) was accomplished by simply sliding the horizontal arm, with the adjustable marker properly positioned, until the marker came into contact with the skin surface. Then, the depth of the foreign body beneath the new marking could be calculated by reading on the horizontal arm the value of the gradation scale superimposed in alinement with the first spotting accomplished on the skin surface of the horizontal plane.

The biplane marker was a sturdy, well-built unit, with no small detachable parts to be lost. It was also an ingenious instrument, and when it was used with the reorientation device (a probe for pointing out the foreign body) could be carried into the operating room. The device could be adapted to the fluoroscopic screen, and its value was enchanced by the use of a Lucite conductor which provided dim illumination from pilot lights, so that spotting could be accomplished by the operator without loss of dark adaptation.

This piece of equipment, however, was used only occasionally. The order placed for 125 units early in the war by the Senior Consultant in Radiology in the European theater did not prove justified. So far as is

[4] The biplane marker was developed and manufactured by the Westinghouse X-Ray Co., Baltimore, Md. Special credit for its development is due to the company engineer, Mr. O. C. Hollstein.

known, only one foreign body was located by this means which might not otherwise have been located.

Reorienting Device

The precise localization of foreign bodies, as already mentioned, had an inherent fallacy in that the position of the patient was necessarily changed while he was moved from the fluoroscopic room to the operating room. In addition, skin markings were often removed during preoperative preparation. As a result, precision localization was largely negated. It was to overcome this difficulty that a reorienting (reorientating) device (U.S. Army item 96191) was developed, also by the Westinghouse X-Ray Co. The device provided for adjustment of three probes in relation to a fixed platform. One of the probes was directed to spotting in the uppermost horizontal plane; that is, with localization by way of the roentgenoscopic procedure itself. The second probe was then extended to the spotting provided by the biplane marker, the relations of the roentgenoscopic and biplane localizations thus being restored. The third probe was intended to guide the surgeon along the plane of his theoretical incision. The probes and their accessory components could be sterilized and handled under aseptic conditions .

OTHER ITEMS OF EQUIPMENT

Lightproof Tent

If daylight fluoroscopy could have been made practical, it would have been ideal. On the surface, it seemed possible to develop a bonnet to provide for it, but the idea was rejected for several reasons:

1. It was highly probable, if this equipment had existed, that the roentgenologist would be under pressure to proceed with his observations before he became fully accommodated to the darkness and that diagnostic errors and deficiencies would result.

2. The hazard of overexposure of both patient and operator would exist by oversettings of milliamperes to compensate for the lack of total dark adaptation.

3. Unnecessary exposure of both patient and operator would also result from the use of abnormally large fields.

Since the bonnet for daylight fluoroscopy was considered both unwise and impractical, a special lightproof, multiple-purpose tent (fig. 25) was developed, to be used for roentgenoscopy or film processing. The entrance and exit flaps were adjusted according to the current use of the tent. When the tent was used for roentgenoscopy, the front curtains were arranged to permit easy ingress or egress. When it was used for film processing, they were arranged in labyrinth fashion. The supporting structure was so de-

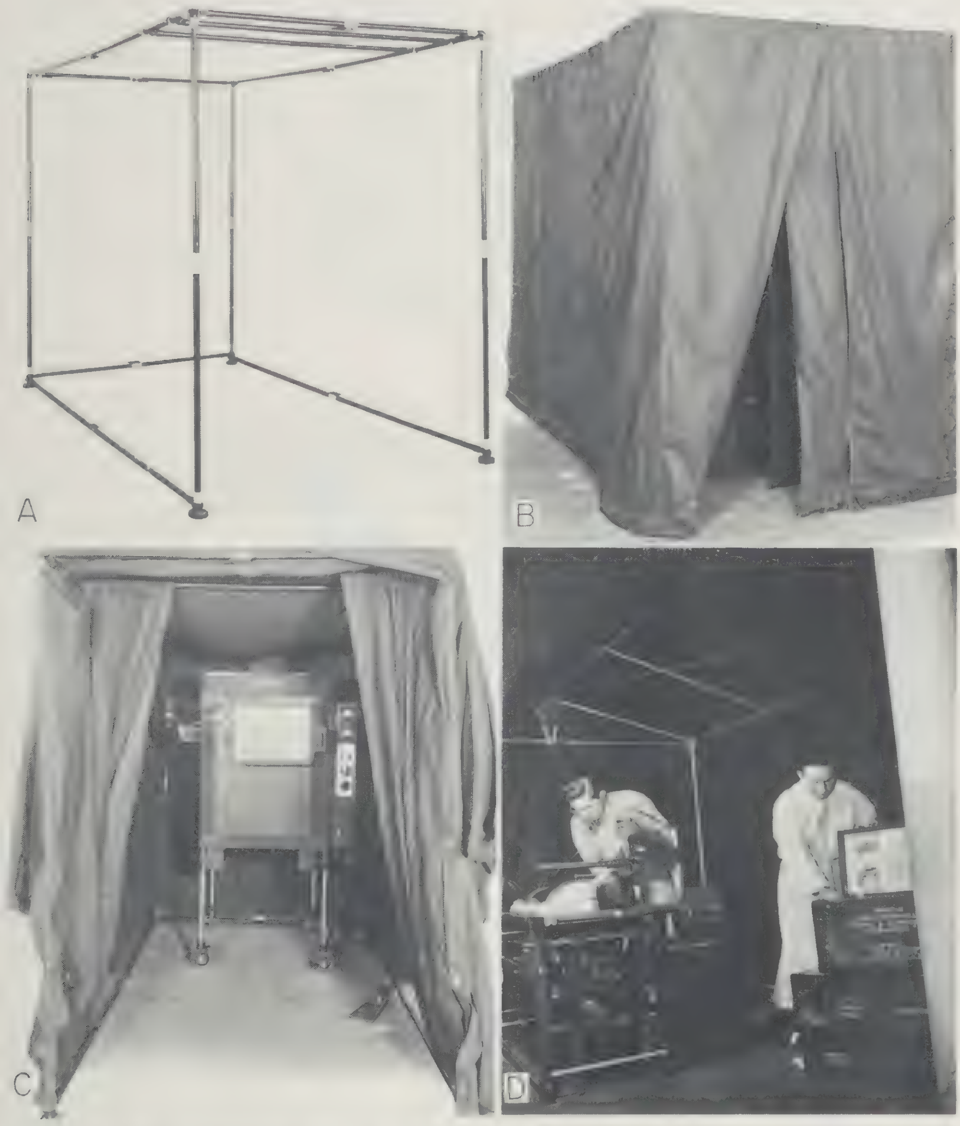

FIGURE 25.—Darkroom tent. A. Frame. B. Exterior of tent. C. Interior of tent, ready for fluoroscopy. D. Darkroom tent set up within another tent, ready for fluoroscopy.

signed that the tent could be set up by itself or used inside a room, a larger hospital tent, or an underground tunnel.

Since the tent had to be lightproof, even under a midday tropical sun, very fine mesh canvas was required. The Capital Awning Co., Washington, D.C., displayed special interest in the preparation of specifications and pro-

duction of pilot models, and the tent finally produced was lightproof, fireproof, mildewproof, and highly versatile.

With its advantages, however, the tent was not heatproof. Radiologists and technicians who served in the tropics and other hot and humid areas can vividly recall the horrors of the tent on a hot day when operator, patient, attendants, technicians, and equipment were all crowded together into its small confines.

The tent also had another defect, that after repeated foldings, unfoldings, and shipments, it began to leak light, which sometimes made it necessary to erect one tent within another. This situation occurred in both the Pacific Ocean Areas (p. 618) and the European theater (p. 364).

Film Processing Unit

The development of an adequate film processing unit went through three phases:

1. A basic tank of lightweight material was planned and constructed, consisting of separate tanks for developing and washing the film. These tanks had internal baffles and were so constructed that there was continuous circulation of water from top to bottom to top, where it was used for washing. When this model was tested, a bottleneck was at once revealed, in that the fixing (hypo) tank was not large enough to handle the production capacity of the developing tank.

2. In the second phase of development, a separate tank, of different design, was provided for the washing-fixing operation. The bottleneck described was thus overcome, and processing could be accomplished simply and rapidly.

3. Almost as soon as these designs were worked out and specifications for them prepared, the materials originally used became unavailable. As a result, the tanks had to be redesigned for use of redwood, which thereafter was employed in their construction.

The final film processing unit (U.S. Army items 9611500 and 9611700) consisted of a master chemical section and an auxiliary wash section, each of which contained a tank and a pedestal (fig. 26). The master chemical section was large enough to permit the use of insert tanks, the size of which depended upon the type of hospital installation involved. The pedestal section served to circulate water from the main tank into the heating or cooling compartment or both (the elements of both were thermostatically controlled). The auxiliary wash section resembled the master chemical section in appearance and had the same physical dimensions and capacity, but its pedestal unit lacked the components for water circulation, refrigeration, and heating. These tanks could be connected to the community water supply, or, if this was not possible, continuous circulation of a bucket supply of water was satisfactory.

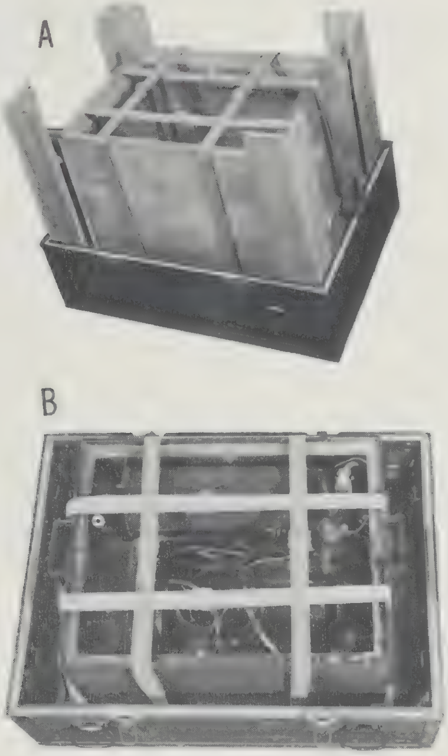

FIGURE 26.—Final model of film processing unit. A. Tank chemical section, partly packed for transportation. B. Pedestal section (partly packed), designed to circulate water into cooling or heating compartment.

Stereoscopic Cassette Changer

With the assistance of H. G. Fischer and Co., Chicago, a stereoscopic cassette changer of the field type was developed. This device could be set up in a few seconds and could be used with either field or standard equipment. The cassettes could be released by remote electrical control.

Combination Film Drier and Loading Bin

A satisfactory film drier and loading bin combination for field use (fig. 27) was obtained from the Buck X-Ograph Co. by slight modification of an existing commercial unit. The apparatus (U.S. Army Unit No. 9605500) was designed in two sections, for ease of handling, and was so

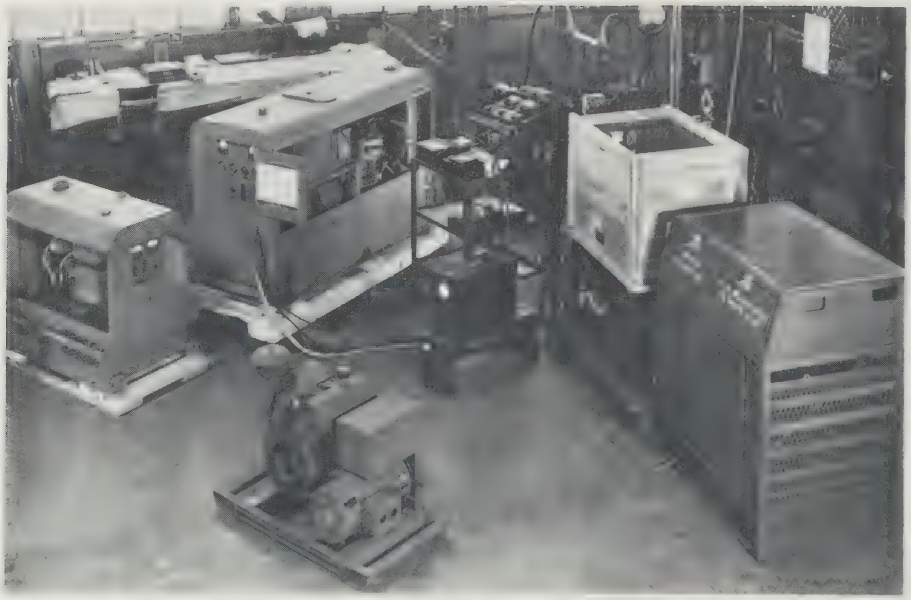

FIGURE 27.—Scene in Buck X-Ograph factory, with combination film drier and loading bin (lower right) awaiting shipment.

arranged that it could be used in the smallest hospital installation and, in multiples, for the largest medical installations in which it might be required.

Gasoline Electric Generator

Roentgenologic equipment requires a steady, predictable source of power, which, it was realized, would not always—or perhaps would not often—be available from local sources. It was also realized that, because of the rather large requirements of X-ray equipment, it would not be practicable to depend upon the field generating equipment of the hospital in which the department was located. Obviously, an independent source of power, from a small portable generator, must be supplied.

The ordinary commercial generator, with a capacity below 5 kw., was not suitable for roentgenologic use. Distortions in waveforms, line surges, and inefficient governor control all made it undesirable. Conventional generators were not designed to handle sudden fluctuations of load, such as that produced by energization of X-ray apparatus. They were also unsatisfactory when only half the wave was utilized (except for smaller loads concerned with heating of the filament). The generator selected had to have the characteristics for efficient performance without tube and cable failures.

Numerous small generators were tested, and for constancy of performance and simplicity of operation, one manufactured by D. W. Onan & Sons

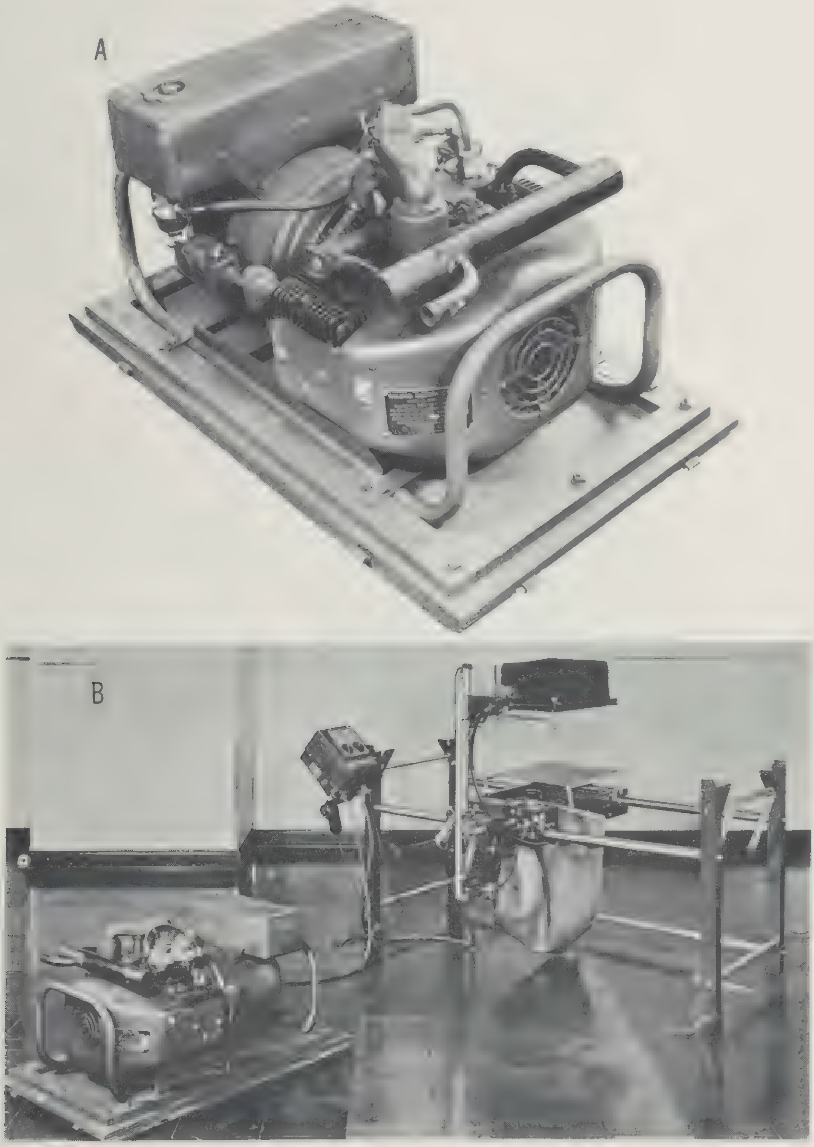

FIGURE 28.—Portable gasoline generator, capable of supplying 2,500 watts continuously for 4 hours. A. Closeup of generator. B. Generator set up to power light airflow table unit.

was selected (U.S. Army item 9606000). This generator (fig. 28), which weighed 357 pounds packed, served as a dependable source of 60-cycle, single-phase, alternating current; it delivered 2,500 watts for 4 hours on 2 gallons of gasoline and, from reports received from the field (p. 378 and p. 527), it proved a sturdy and practical machine when it was consistently and correctly cared for.

Conventional commercial equipment was, of course, supplied to installations in the Zone of Interior.

Portable Transformer Unit

Naturally, whenever possible, it was desirable to utilize local electrical current rather than the field generator to operate electrical equipment. There were, however, two problems to be overcome:

1. Some means had to be devised to utilize currents ranging from 100 to 260 volts at both 50 and 60 cycles, such as would be encountered at various places over the world.
2. Many foreign sources provided 3-phase rather than single-phase current.

To build each individual item of equipment to accommodate such a range of inputs would have increased bulk, weight, and costs to an unreasonable degree. A better solution was the development of a portable transformer (fig. 29) which could reduce voltages up to 260 v. to 110 v. and could convert 3-phase to single-phase current. This transformer weighed 80 pounds and contained 70 feet of line cable to plug into existing power supplies.

If the frequency of the available current was less than 50 cycles (frequencies of 25 to 30 cycles were not uncommon in various locations), the field generator had to be used, as the portable equipment was designed only for 50- and 60-cycle operation.

PACKING OF EQUIPMENT

Packing chests were provided for all items originally intended for use in mobile installations. Such equipment as the combination film loading bin and drier and film processing units were shipped by the manufacturer in ordinary packing crates. Later, at the Army School of Roentgenology, a chest was constructed to permit accommodation of all such items, which were secured by internal bracings, fixation straps, and supporting panels (fig. 30). Usually space remained for additional items such as films, chemicals, and linens. The chest, when emptied, could be used as a desk, table, storage cabinet, or clothesrack. There was also provision for plumbing connections, so that it could be used as a 90-gallon water tank or an auxiliary wash tank (fig. 30F).

PROTECTION AGAINST RADIATION

Critical Comments

Interest in radiation hazards was perhaps not so widespread in the prewar and early war years as it is at this time (1963), but at that, protection was an important, and frequently controversial, consideration among

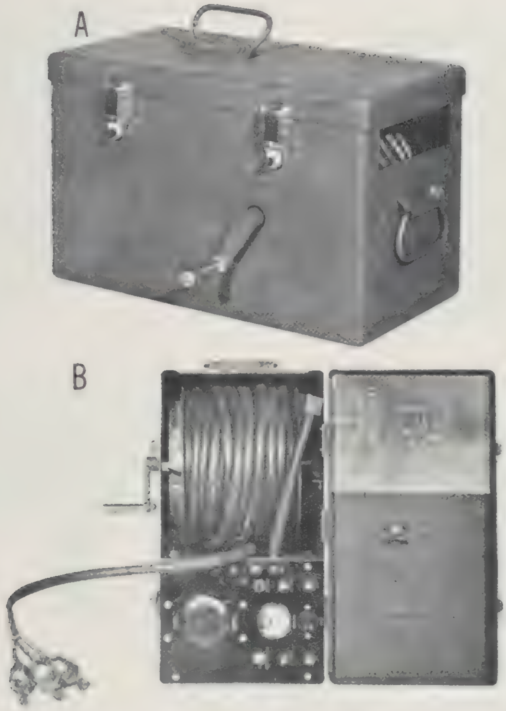

FIGURE 29.—Portable autotransformer. A. Transportation chest. B. Chest opened, to show 70-ft. cable ready for fixation to open leads, such as are available in distribution box. Note meter for indicating voltage applied to electrical apparatus connected with secondary circuit of autotransformer winder.

radiologists. At the 26th annual meeting of the Radiological Society of North America in Cleveland in December 1940, a combination field X-ray unit (manufactured by the Picker X-Ray Corp.) and a table unit (manufactured by the Westinghouse X-Ray Co.) were displayed and comments were invited. The same equipment was also sent to various general hospitals for comments by military radiologists. Testing of equipment and surveys of radiation hazards were conducted in a number of civilian institutions. In August 1941, Drs. Leonard A. Scheele and Dean B. Cowie published an analysis of radiation protection in 45 civilian hospitals (*18*).

Almost as soon as this article was published, a nationally prominent roentgenologist wrote to the senior author: "May I ask Dr. Scheele if the newly designed fluoroscopic unit for the Army has been checked for the effect of radiation on the operator? It looks to me to be the most flagrant violation of the rules of fluoroscopy that I have ever seen."

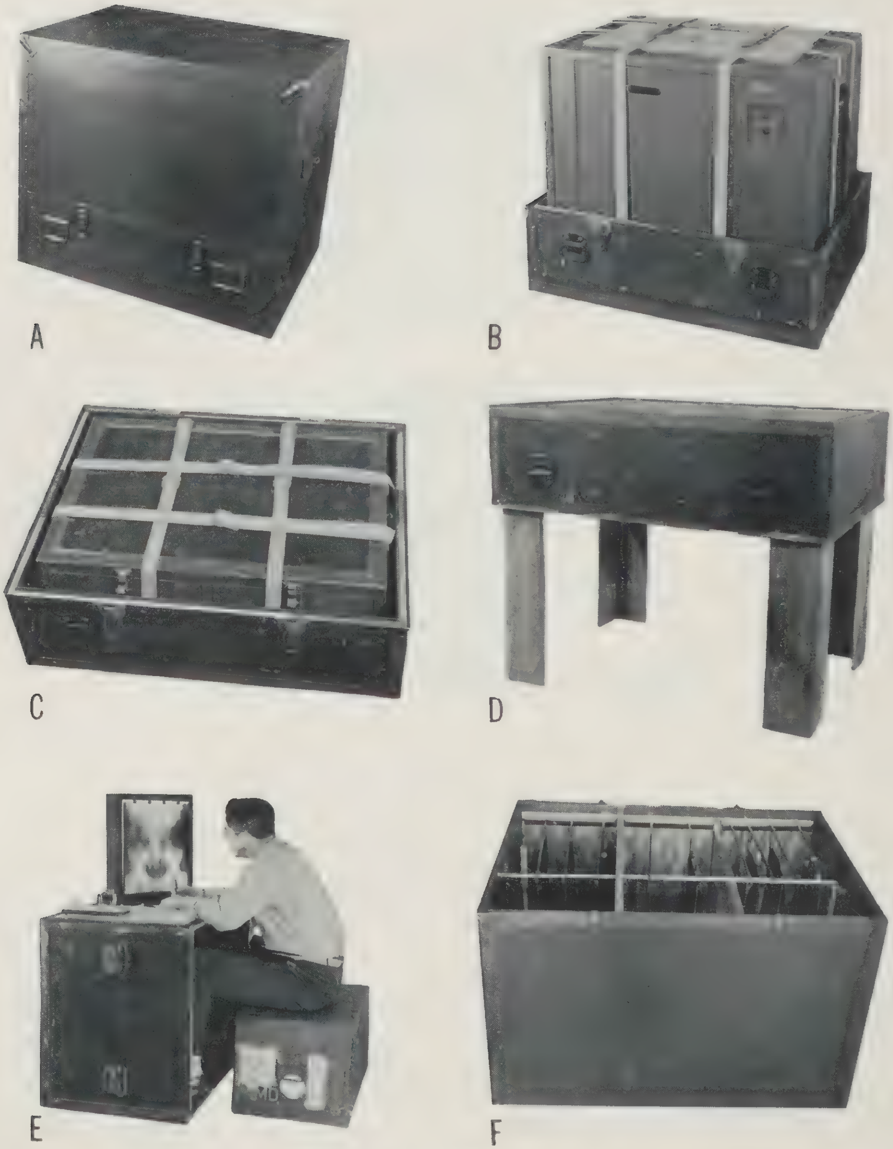

FIGURE 30.—Field packing chest developed at Army School of Roentgenology. A. Exterior of chest. B. Drier, fixed by straps, packed in lower section of chest. C. Loading bin, fixed by straps, packed in lower section of chest. D. Lower section of chest used as table. E. Top section of chest used as desk. F. Top section of chest converted into reserve auxiliary wash tank. Any bulging of sides caused by large volume of water could be corrected by using fixation straps for reinforcement.

Meantime, more objective criticisms of the Army equipment and a number of picayune complaints had been received, many of which were sent directly to The Surgeon General. Others were sent to the Army Medical School. A well-qualified roentgenologist in active service wrote as follows: "I understand that Dr. —— had just reported that an Army field x-ray unit scatters considerable radiation and that the amount radiating to the head and neck is greater than the daily tolerance dose. Because of this I am extremely anxious to protect my men and myself from excessive exposure. I would rather have just one or two x-ray machines and be adequately protected than to have a display of eight or nine machines and have no protection." In fact, the writer of this letter concluded, he would prefer one conventional X-ray to five or six field units.

Another typical letter read: "What are the needs for roentgenolographic technicians in the service? I understand there is a considerable hazard associated with this work in the Army. A friend told me that one is likely to become sterile in the course of such an assignment; is this true?"

Obviously, the implications of these communications, that commercial X-ray equipment was safe and Army field equipment was not, could not be allowed to stand. The efficient use of Army equipment, as well as the morale of those using it, would be seriously affected if action were not taken at once. Something stronger than mere rebuttal of the charges was needed; therefore, whenever it was possible, the critics of the equipment were invited to participate in further testing of the Army equipment and in experimental studies on it.

Results of Special Studies

The results of these tests and experiments were presented at the 43d annual meeting of the American Roentgen Ray Society in Chicago on 15–18 September 1942 (*19, 20*), the following main points being developed:

1. A fixed focal-roentgenoscopic screen alinement and distance have been set for roentgenoscopy. This requirement obviates malalinements of the primary beam or changes in its coverage by the roentgenoscopic screen such as might apply if the screen were allowed to move independently in relation to the roentgen tube. Many roentgenologists have advocated the use of a bonnet type roentgenoscope, so that observations might be made in a lighted room, but this plan, and others similar to it, have been rejected by the Medical Department because they would entail too great a hazard to the operator.

2. The roentgenoscopic screen is 12 by 16 inches. This is a large field, which provides a large measure of protection against secondary radiation from the patient. Many roentgenologists recommended, in order to reduce weight and to facilitate exchange of patients, that the dimensions of the screen be reduced to 10 by 10 inches, the size of the screen used in World War I. These advantages have been sacrificed in favor of protection.

3. During foreign body localization, the skin surface is marked by a

special device that can be manipulated beneath the roentgenoscopic screen without exposure of the operator's hands to the primary beam. This arrangement is possible because the distance between the roentgenoscopic image and the skin surface is subtracted in the final adjustment of the depth scale, and it is not necessary to position the roentgenoscopic screen directly upon the skin surface.[5]

4. Stops are provided to limit the opening of the roentgenoscopic shutter, so that the border of the primary beam is restricted to at least 1 inch within the protective limits of the roentgenoscopic screen. Even with the most careless operation of the shutter controls it is therefore not possible for any part of the primary beam to escape beyond the limits of the protection afforded by the screen and its lead glass, which is equivalent to not less than 1.5 mm. of lead.

5. The roentgenoscopic screen and the roentgen tube are mounted on a C-shaped support that is adjustable in the vertical plane. This arrangement permits variation of the focal skin distance and utilization of the greatest possible focal skin distance during localizations. Roentgen radiation exposure of the patient is thus minimized and secondary radiation from the tissues is concurrently reduced. It is advantageous to utilize this arrangement for another reason, that it provides optimum visualization by improving contrast and sharpening detail.

6. Except for the portal for exit of the primary beam, the roentgen tube housing is impregnated with material possessing a protective equivalence of no less than 1.5 mm. of lead.

7. The combined inherent filtration through the portal intended for the primary beam is equivalent to 0.5 mm. of aluminum. This filtration consists of the wall of the insert tube (1.0 mm. of Pyrex glass), a thin (1.5 mm.) layer of oil, a transparent Bakelite wall (1.5 mm.), and an added fixed filter of 0.25 mm. of aluminum. Unnecessary soft irradiation is thus eliminated, but intensity sufficient for roentgenography is preserved.

8. For roentgenoscopy, in addition to the filtration just described, a second fixed filter of 0.5 mm. of aluminum is provided. This filter is fixed into the housing of the roentgenoscopic shutters. The total filtration during fluoroscopy is thus consistent with the stipulation in paragraph 2.03 of "Handbook HB–20," as compiled by the Advisory Committee on X-ray Protection and as published by the National Bureau of Standards.

9. The shutter controls are contained in the vertical portion of the C-shaped supporting member just mentioned, at a liberal distance from the primary beam and the sources of secondary radiation. This feature minimizes exposure of the examiner's forearm and lessens the tendency for him to lean

[5] In World War I, a perforation was provided in the center of the fluoroscopic screen to permit insertion of a screen marker. A very conscientious roentgenologist, who made his alinements by viewing as nearly as possible directly over the perforation, would be rewarded for his pains by receiving primary or secondary radiation. A less conscientious operator would be spared the exposure.

closely toward the side of the patient, where he would receive more extensive exposure.

10. The technique adopted for foreign body localization (p. 74) requires only three short exposures for alinements and can be accomplished within 30 to 45 seconds. Even with the shortest focal skin distance (10 inches, which allows for a heavy patient and the sag of a very old litter) and using 85 kv. (peak) and 5 ma., the dose at the skin would be approximately 15 r. The depth scale can be read only while the roentgen ray exposure is interrupted, in contrast to many other techniques that provide for reading of measurements by means of fluorescence from the roentgenoscopy screen.

11. An adjustable limiting resistance is incorporated into the control, so that when the thumb switch or foot switch is used, one or the other being required for roentgenoscopy, the maximum milliamperage load can be limited to 5 ma. or any lesser value.

12. The fastest possible type of roentgenoscopic screen is provided, and exposure requirements are thus reduced.

13. The tabletop is a standard U.S. Army litter, constructed of canvas and aluminum, both materials of low atomic number. The secondary roentgen radiation emitted from a litter tabletop is considerably less than that emitted from conventional tops, and another source of secondary radiation is thus reduced.

14. The field chest which accommodates the control unit of the X-ray machine contains a lead-impregnated apron and a pair of lead-impregnated gloves. It is thus certain that at least one apron and at least one pair of gloves will be part of the equipment of every installation in which an X-ray machine is operated. Moreover, the use of the apron and gloves is not permissive; it is required that this equipment be worn while the field X-ray machine is being operated. The supporting straps of the apron provide for suspension from the shoulder to the opposite hip, not from the neck, so that the operator wears this rather cumbersome protective article with maximum comfort. The standard gloves have a length of 37 cm., which is somewhat longer than that of gloves in use in many civilian clinics. All aprons and gloves are tested at the Army School of Roentgenology, and unless they meet all requirements, including the requirement that a single thickness of both aprons and gloves shall provide protection equivalence of no less than 0.5 mm. of lead, they are rejected.

15. The auxiliary lead-impregnated shield supplied as a separate item can be adapted to either end or either side of the table unit. It is designed to protect the legs of the operator below the bottom of the lead rubber apron. He, his assistants, and the observers present are thus protected throughout the arc of greatest intensities of scattered radiation; that is, the lateral and downward trajectories with respect to the roentgen tube and screen.

16. Apron, gloves, and shield are carried as separate items, so that they can be reordered as necessary, for all tend to deteriorate.

17. Longer cables than those ordinarily used are provided, to give the operator maximum protection.

18. Several types of instruction manuals are provided, issued by the manufacturers as well as by the Army. Technical Manual 8–275 (p. 574) includes a chapter dealing with roentgen-ray hazards and stressing the possibilities of injury and the limitation of protection that can be expected.

The various studies made of radiation hazards showed that when apparatus such as the Army field unit was used for horizontal fluoroscopy, the distribution of stray radiation above the tabletop was essentially the same as with conventional X-ray equipment. Since the medical officer was required to wear a lead-impregnated apron, it was only below this apron that he could possibly receive excessive radiation.

In this area below the apron three important components had to be considered: (1) Leakage of primary and stray radiation from within the tube housing itself, (2) secondary radiation from the shutters and their housing, and (3) secondary radiation from the patient. It was the function of the auxiliary lead-impregnated shield, as just pointed out, to protect the knees, legs, and feet of the operator from these components. This shield, in conjunction with the lower part of the lead-impregnated apron, served in much the same way as the metal side panels on a totally enclosed heavy-duty roentgenoscopic table.

Representative Ionization Measurements

The data contained in table 1 are representative of ionization measurements made with the Army field table, without the protection of the lead-impregnated apron. They were selected from extensive testings carried out by several observers. All measurements were made with the tube in the middle

TABLE 1.—*Ionization measurements with standard Army field table unit*
[Roentgens per hour measured at knee and foot for operators not wearing aprons]

Observer	Knee	Foot	Size of phantom	Field at screen
Glasser [1]	0.048	0.048	25 x 25 x 25 cm.	25 x 25 cm.
Picker [2]		0.036	25 x 25 x 25 cm.	25 x 25 cm.
Wintker [3]	0.023	0.008	20 x 31 x 21 cm.	25 x 25 cm.
de Lorimier, Cowie, and White.	0.020	0.020	20 x 31 x 21 cm.	20 x 20 cm.

[1] Dr. Otto Glasser, Cleveland Clinic Foundation.

[2] Picker X-Ray Corp. (Mr. E. R. Goldfield and Mr. Tom Callaghan).

[3] 1st Lt. (later Maj.) Franklin R. Wintker, SnC, Department of Roentgenology, Army Medical School.

Source: de Lorimier, A. A., Cowie, D. B., and White, T. N.: Protective Features Provided With the United States Army Field Roentgenoscopic Equipment. Am. J. Roentgenol. 49: 653–661, May 1943.

position of table width and in the far and near positions. All data are maximum values and are based upon the outer limits of roentgenoscopic factors; that is, 85 kv. (peak) and 5 ma. All concern continuous exposures. It was estimated that, allowing for the exchange of patients, the marking and making of adjustments between exposures, and the intermittent interruptions of common occurrence, the equipment was actually energized for about 25 percent of the time; 2½ hours of continuous operation might therefore be considered the equivalent of a 10-hour day of roentgenoscopic activity. If the exposure values presented in table 1 were adjusted for a 10-hour day (multiplying by the factor of 2.5), the summation values would be well under the recognized permissible dose.

Official Approval

The findings just reported were later corroborated by the Subcommittee on Radiology of the Committee on Surgery of the National Research Council, whose membership consisted of Dr. Arthur C. Christie, chairman, Dr. Byrl R. Kirklin, Dr. Urnus V. Portmann, Dr. W. Edward Chamberlain, and Dr. Eugene P. Pendergrass (*21*). After reviewing the structural features of the field unit, examining it, and analyzing the radiation tests that had been conducted, this Subcommittee " * * * moved and carried that it is the considered opinion of this committee that all fluoroscopic equipment furnished by the Army has ample protection for those working with it if the equipment and accessory apparatus furnished is used according to instructions."

Up to this time (November 1942) the Office of The Surgeon General had made no official inquiry concerning the reliability of the protection features incorporated in the field X-ray table and the field X-ray machine unit. The expression of the Subcommittee on Radiology was therefore doubly appreciated for it undoubtedly helped to forestall the inquiry which would otherwise have been inevitable later.

TESTING OF EQUIPMENT

It has always been part of the responsibility of personnel in the Medical Department concerned with teaching to advise The Surgeon General concerning items of equipment, including defects and deficiencies. This function was especially important during the war years, when supplies and equipment sometimes had to be purchased from suppliers with whom there had been no previous contacts. All items were tested from the standpoint of their possible military use. This work was carried out at the Army School of Roentgenology (p. 30). The items tested and reported on during 1943–44, as listed in the annual report for that period, included:

1. The Berman locator, which was not considered practical for general military application.

2. Plastic cassettes. The samples tested possessed serious defects. Had

plastic proved practical for this purpose, its use would have reduced the weight of the cassettes and saved critical material.

3. Morgan X-ray exposure meter (p. 162). This meter was useful but had only a limited military applicability.

4. Shockproof cables, developed by the Picker X-Ray Corp. They were reported as satisfactory for field X-ray units.

5. Hangers for photoroentgen films, developed by the Westinghouse X-Ray Co., for simultaneous processing of large numbers of films. The design was tentatively approved pending slight modification in size, to make the hangers adaptable to Army field X-ray driers.

6. Extension cables for Army field X-ray units, developed by the Picker X-Ray Corp. for increasing the distance between the control unit and the X-ray tube, to provide greater protection to X-ray personnel. These cables, which were approved and for which specifications were written, were intended chiefly for permanent X-ray installations in general hospitals overseas.

7. Aster X-ray solutions. These chemicals were found to develop more film surface per unit of solution, and in a shorter time, than other brands, but assurance of uniform quality was doubtful and they were not approved.

8. Radar. Extensive tests on radar equipment were carried out by personnel of the School at the Anti-Aircraft Artillery School, Camp Stewart, Ga., and an official report of the findings was made.

RESEARCH AT THE ARMY SCHOOL OF ROENTGENOLOGY

Even though basic designs of X-ray equipment had been approved and production was in high gear when the Army School of Roentgenology was moved to Memphis, Tenn. (p. 30), research was considered an important function of the school. Comments on the apparatus in use were received in a steady stream and stimulated further investigation and development. It had always been hoped that an X-ray unit could be developed with such components that, with the least coupling, its performance would satisfy the needs of the smaller stations and that, with increments of its working parts, it would become more versatile. It was even planned that, by interconnecting a valve tube component, the capacity of this unit would be so increased that it would satisfy the needs of a large station hospital and the secondary needs of a general hospital. In short, the objective was to develop an X-ray machine for military use which would also be serviceable in times of peace, so that, if war came again, radiologists and technicians would not be abruptly called upon to deal with strange equipment.

The following research projects were conducted at the Army School of Roentgenology in 1943–44, a year when the chief emphasis was on teaching, and in 1944–45, when greater emphasis on research and development was possible:

1. Film life. Studies were made on residual hypo and its effect on film life and on photoroentgen films.

FIGURE 31.—Tunnel for changing cassette without disturbing patient was particularly useful at bedside.

2. Calibration of intensifying screens.

3. Fluoroscopic screens. The purpose of this project was to ascertain the causes of breakage of the screens and to devise corrective means. Poor packing was invariably found to be the cause. New methods of packing screen units were devised and were proved satisfactory on rigorous tests.

4. Serialographic attachment for fluoroscopic screens. The final design could function as:

A. A spot-film device, utilizing an 8- by 10-inch film, applied either horizontally or vertically, and providing for automatic changeover of the milliamperage from that of a fluoroscopic load (2–5 ma.) to that practical for roentgenography (15–30 ma.).

B. A serialographic device, with a modification to permit two 4- by 5-inch exposures on an 8- by 10-inch film.

5. A tunnel-changer, which might be used at the bedside (fig. 31) or on an X-ray table under the patient, to provide for shifting of cassettes and for making a stereoscopic pair of roentgenograms.

6. An angle board, to permit angulation of the film and of the part under investigation. This board was particularly useful in studies of the skull and paranasal sinuses.

7. A cradle (fig. 32), to suspend the head of the patient beneath a cassette, so that roentgenography could be accomplished with the X-ray tube under the table. This cradle was particularly useful in maxillofacial fractures, in which weight upon the injured area could not be tolerated.

8. A kymograph. A cassette-moving mechanism and a special kymographic device was built into 5 of the 10 pilot models, to provide for roent-

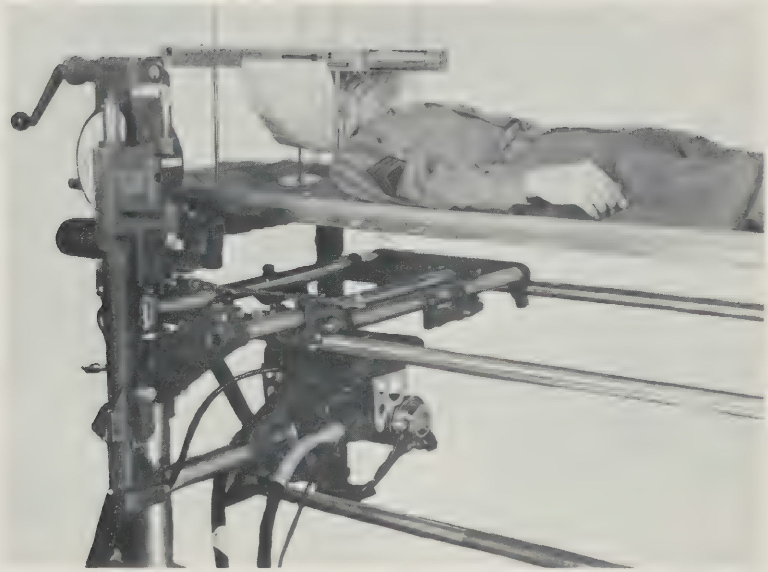

FIGURE 32.—Cradle for suspending head when damage to facial bones prevented prone position.

genographic tracings of amplitude changes during various phases of functioning of such an organ as the heart.

9. Motor mechanism for operation of tube and screen in vertical position. This item was devised to facilitate up-and-down movement of the C-shaped member of the apparatus used for vertical roentgenoscopy (item 9614500). The working model proved easily adaptable to the table unit and was found to be entirely practical, but wartime shortages precluded obtaining a suitable motor to complete the project.

10. Transformer for field X-ray unit. This project was not completed during the war but the basic principles of the design were utilized later.

11. Functional packing. This project has been described elsewhere (p. 82).

12. Stereoscopic unit. The objective of this project was the development of a lightweight, collapsible unit to provide for stereoscopic viewing in the field. The apparatus, including two standard film viewing boxes, was to be accommodated in the standard Medical Department field chest. A preliminary model was constructed but the war ended before the project was completed.

13. Combination unit. The objective of this project was to answer the demands of roentgenologists in the field for a rigid tabletop, a moving grid, a support for vertical roentgenography with provision for Bucky diminution of secondary radiation, and a field stereoscopic cassette changer. The basic design was completed, and a manufacturer's model was constructed before research activities at the School of Roentgenology ended with the end of the war.

14. Film marker. The aim of this project was to provide a means of uniform identification for films. It was finally decided, after a number of other plans had been tested and discarded, that a flasher system was most practical and should be used in conjunction with the usual X-ray request slip after the slip had been slightly modified. The system was accepted officially, and four models were constructed in the school workshop before the war ended.

15. Four-valve rectification component for field X-ray unit. The objective of this project was to enlarge the roentgenographic capacity of the field X-ray machine. Information was received from every theater that conventional commercial equipment was impractical because of excessive breakages. On the other hand, equipment with high milliamperage capacity was needed in general hospitals. Since the field X-ray unit, once initial difficulties had been overcome, withstood transportation and use in wartime conditions, it was thought practical to develop an additional chest containing four-valve tubes and their respective step-down transformers. These components were to be identified as separate items and used as auxiliaries to the machine unit. They would provide for full-wave utilization and thus permit loads as great as 100 ma., such as were desirable in general hospitals, at the same time utilizing self-rectifications with limitation of loads to 30 ma., such as were practical in forward hospitals. The basic design of this item was accomplished.

Termination of testing and research functions.—At the end of the war, when the Army School of Roentgenology at the University of Tennessee College of Medicine was closed, its equipment was moved to Brooke Army Medical Center, Fort Sam Houston, Tex. Here, the school continued to function in its teaching capacity but was shorn of its research and testing functions. This can be regarded only as extremely unfortunate, for all experience shows that the combination of testing, research, and teaching in a single institution assures cross-fertilization of ideas and progressive development of teaching philosophies and their practical implementation.

EVALUATION OF FIELD EQUIPMENT

Obviously, in spite of every effort on the part of all concerned, universally satisfactory X-ray equipment could not be developed during the war, particularly under the circumstances in which the work had to be done. Equally obviously, the equipment developed was not so versatile that it was completely adaptable to all military situations, which ranged from fast-moving combat, as in the European theater or amphibious and tropical warfare to civilian-type care in a stationary installation in the Arctic area. Under these strains, deficiencies did develop and were duly reported to The Surgeon General. Some of the criticisms were trivial and of little substance; others were thoughtful and well worth careful consideration.

A meeting was convened at Carlisle Barracks, Pa., in March 1945, to discuss these criticisms, to hear direct reports from radiologists in the field,

and to evaluate the field equipment from all points of view. It was attended by radiologists from various theaters of operations, the commandant and other representatives of the Army School of Roentgenology, and representatives of X-ray manufacturing companies.

This meeting confirmed what had been suspected for some time concerning the use of roentgenoscopy as a diagnostic tool in the field. Before the war, it had been the general opinion that roentgenoscopy rather than roentgenography would predominate in forward areas, just as in World War I. The reverse was true. The surgeons of World War II, who were roentgenologically conscious because of their civilian experience, wanted to see roentgenographs before proceeding with surgery. Even for foreign body localization, many physicians preferred anterior and lateral film studies, regardless of the distorted anatomic relations, to more accurate and more rapid fluoroscopic localization. The localizing device was simply not used.

Another reason for the popularity of, and the demand for, radiographs was the desire to have them for inspection in the operating room and also to have them for permanent incorporation in the patient's file.

The demand for roentgenography instead of roentgenoscopy in forward areas required films, film-processing and storage facilities, chemicals, and darkroom equipment in the highly mobile field and evacuation hospitals in these forward areas.

The field equipment was regarded as generally satisfactory, but requests were made at the meeting for numerous types of accessory equipment and for modifications in the present equipment. Among the items requested were the following:

1. Tunnel changer.
2. Spot film and serialographic devices.
3. Angulation boards.
4. A rigid tabletop, in place of the litter currently in use.
5. Equipment that would permit easier handling of the patient for roentgenography.
6. A moving Bucky-Potter diaphragm, on the ground that the factor of movement of the grid (versus grid ratio) was all important in relation to cleanup of scattered radiation and fogging.
7. A standard type of stereoscopic cassette changer (pp. 379 and 615).
8. A field stereoscope.
9. A field unit with an output of 100 ma., as compared with the 30 ma. provided at the time.
10. More rugged equipment. Several radiologists told of seeing delicate X-ray equipment dumped from rope loading baskets of ships onto docks and of the serious damage that resulted.

These various demands were later studied at the Army School of Roentgenology and some equipment was modified (p. 89). Many of the requests, however, were simply not practical. It was an easy matter, for instance, to state the merits of the high amperage of commercial equipment without taking

into consideration the difficulties of providing it in the field, where simplicity of operation and assembly, limitations of weight, and variable sources of power all were factors to be reckoned with. Ruggedness of equipment could not be accomplished without increases in weight, which were, of course, undesirable. What many of these requests amounted to was the provision of capabilities in field units that would match those of permanent commercial installations, and in the field which was simply not possible.

CONCLUSIONS

The roentgenologic experience of World War II suggests certain conclusions in respect to equipment:

1. The imperative importance of having concepts, designs, and specifications in being at all times and ready for expansion.

2. The imperative importance of keeping specifications current; that is, not only abreast of the current status of radiology but, if possible, ahead of it.

3. The necessity for equipment that is light, sturdy, adequately powered, and easily transportable.

Observance of these requirements would reduce, if not eliminate, confusion and delay in the early stages of rapid mobilization and would help to assure prompt attainment of production goals. The situation that prevailed at the beginning of World War II should not be permitted to come to pass again.

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CHAPTER V

Personnel Centers

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The story of radiology in induction centers in the Zone of Interior in World War II is chiefly the story of chest radiology for the detection of pulmonary tuberculosis, so that men with this condition, as well as with other significant pulmonary lesions, would be excluded from the Armed Forces. The production of satisfactory chest roentgenograms and their interpretation were the prime duty of the radiologists assigned to them. X-ray examinations of other parts of the body were carried out as indicated, but not originally at induction centers, because of the lack of equipment.

The attention paid to pulmonary tuberculosis in World War II was a natural outcome of the experience in France in World War I (*1*). There was a high incidence of this disease in British and French troops there, and it was occasionally found in newly arrived U.S. soldiers. Regulations designed to exclude tuberculous subjects from service were rigid, but the stress was on physical signs of the disease. The finding of moist rales on inspiration following cough, for instance, was in itself a sufficient cause for rejection. Little use was made of X-rays, because radiographs were not then being produced on a mass basis, and the interpretation of the films and the reliability of radiologic diagnosis had not yet been fully established. Little was known about clinically silent lesions, and no stress was placed on them, probably because, on the poor roentgenograms then produced, minimal lesions were not recognized.

The emphasis on physical findings in the diagnosis of pulmonary tuberculosis that prevailed during World War I was continued after the war, and the criteria then employed were repeated in MR (Mobilization Regulations) 1–5, issued in December 1932 (*2*).

DEVELOPMENTS BEFORE WORLD WAR II

Meantime, a different point of view was developing, and in the decade before the United States entered World War II there was a notable increase in the understanding of pulmonary tuberculosis, chiefly because of the development of refined radiologic equipment and techniques.[1] The Office of The

[1] The account of the development of policies relating to pulmonary tuberculosis is told in detail in volume II of the Internal Medicine Series in the history of the U.S. Army Medical Department in World War II (*3*).

Surgeon General was quite aware of these advances, and by 1935, chest X-rays were required for all Regular Army troops going overseas as replacements, for all officers entering the service, and for all enlisted men and officers on their separation from service (*4*). By 1939, all Reserve officers reporting for extended active duty were also given chest X-ray examinations (*5*).

Before describing official actions that led to the institution of chest X-rays before induction in World War II, the activities of nonmilitary groups might be mentioned. The National Tuberculosis Association, for instance, conducted numerous discussions on the subject, and on 2 June 1941, the managing director sent to The Surgeon General a resolution adopted by the board of directors advocating universal chest X-rays for all recruited personnel. The Committee on Military Affairs of the American College of Chest Physicians advocated the same policy. The matter was frequently mentioned in the lay press, and on 14 April 1941, *Time* published an item captioned "TB Warning," stressing the great importance of chest X-rays of all registrants to prevent induction of men with pulmonary tuberculosis.

OFFICIAL ACTIONS

On 8 September 1939, a week after the outbreak of World War II, the President declared a Limited National Emergency. On 16 September 1940, he approved Public Law 783, 76th Congress, the Selective Training and Service Act of 1940. On 27 May 1941, he declared an Unlimited National Emergency. On 18 August 1941, he approved Public Law 213, 77th Congress, the extension of the Selective Service Act of the previous year. These dates should be borne in mind in the account of radiologic activities that follows.

1939

The Professional Services Division, Office of The Surgeon General, of which Col. (later Brig. Gen.) Charles C. Hillman, MC, was Director, had interested itself, for a considerable time, in routine X-rays of the chest for military personnel. In April 1939, on the recommendation of The Surgeon General, The Adjutant General directed that chest X-rays be part of the examination of all Reserve Corps officers to be commissioned in the Army (*5*). Similar directions were again given for Regular Army officers in September 1940 (*6*). Physical standards were somewhat relaxed for officers accepted for limited service, but there was no relaxation in connection with pulmonary tuberculosis: The chest X-ray must be negative, and any other chronic disease of the chest must be excluded. The same restrictions were repeated in March 1942 (*7*).

During mobilization activities in November 1939, Colonel Hillman called to the attention of the Executive Officer, Office of The Surgeon General, the

inadequacy of ordinary physical examination of the chest to detect early tuberculosis, as shown by the Army experience during and since World War I. He mentioned the limited use of chest X-rays at the present time and the possibility of the extension of the plan to include all recruits and draftees in the event of the general mobilization of the Armed Forces already under consideration. He also recommended that a board be appointed to investigate this possibility, and, if the plan was considered practical, to report on the best method of implementing it and on the estimated cost.

As the result of this communication, Office Order No. 140, Office of The Surgeon General, was issued on 14 November 1939, implementing the suggestion that a board be appointed (*8*). It was to consist of Colonel Hillman, Maj. (later Lt. Col.) Martin E. Griffin, MC, and Capt. (later Col.) Alfred A. de Lorimier, MC. The report of the board, made on 14 August 1940, will be summarized in its proper chronologic place (p. 105).

1940

In May of 1940, when the need for defensive mobilization of the Armed Forces seemed imminent, the advice and assistance of the NRC (National Research Council) was requested. Specifically, advice was sought from the Subcommittee on Tuberculosis, Committee on Medicine, Division of Medical Sciences, which consisted of Dr. (later Colonel, MC) Esmond R. Long, Chairman; Dr. J. Burns Amberson, later Chairman; Dr. Bruce H. Douglas; Dr. Herbert R. Edwards; Dr. Paul P. McCain; and Dr. James J. Waring.

This subcommittee, at the request of Colonel Hillman, met on 23 July 1940, to make immediate recommendations for revision of the criteria used in the Army for the diagnosis of pulmonary tuberculosis (*9*). The meeting was attended by representatives of the Medical Corps of the Army and the Navy and of the U.S. Public Health Service.

The committee urgently recommended that chest X-rays be required for all registrants under the Selective Service Act then under discussion in Congress, the films to be supplemented by physical examination and laboratory studies as indicated. The rationale of the recommendation was the fact that at least 75 percent of early tuberculosis could be diagnosed only by X-ray examination. It was the opinion of those present that at least 1 percent of the male population of military age had the disease and that a high proportion of the lesions detectable only by X-ray would break down under the strain of military duty, making the hosts incapable of further service and a menace to their comrades.

The committee further pointed out that routine chest X-rays had other advantages. They were more expeditious than physical examination. They would detect conditions in the chest other than tuberculosis that would make registrants unfit for military service. They would amply repay their cost by the conservation of effective military manpower and the reduction of ultimate

pension costs. Finally, they would furnish permanent and authoritative records which might be useful in subsequent medicolegal adjustments.

The report of the board appointed by The Surgeon General in November 1939 to investigate the policy of routine chest X-rays was made on 14 August 1940, by Captain de Lorimier (*10*). It was concerned chiefly with ways and means of implementing the plan. It was the opinion of the board that the method adopted must be accurate and cheap and must be based on a long-range program, utilizing equipment owned by the Medical Department and operated by its inherent personnel. The method must permit rapid production of roentgenograms, as well as rapid interpretation. The films must be easy to file.

It seemed to the board that the photofluorographic methods recently developed (p. 105) and utilizing 4- by 5-inch films best met these requirements (table 2). It therefore recommended that, as soon as the necessary approval of the War Department could be secured and the necessary equipment provided, chest roentgenograms should be made routine for all military personnel and for all Selective Service registrants.

TABLE 2.—*Comparison of methods of conducting roentgenologic studies of the chest on a large scale* (10)

Method	Diagnostic trust	Preserving of graphic record	Expediting of the examination	Availability of supply	Initial cost of auxiliary equipment	Unit cost per examination	Ease of studying
X-ray film 14x17 stereo	1	4	6	1	Canceled	$1.08	3
X-ray film 14x17 single	3	3	4	1	Canceled	.54	3
X-ray paper 2 exposures	3	4	5	1	Canceled	.68	3
X-ray paper, single	4	4	4	1	Canceled	.34	3
Film 4x5 stereo	2	1	3	3	$2,600	10–12¢	1
Film 4x5 single	6	1	3	2	$2,200	6–8¢	2
Film 35 mm. stereo	5	1	2	2	$2,000	1⅓–3¢	1
Film 35 mm. single	7	2	2	2	$1,400	1–2¢	2
Fluoroscopy	8	None	1	1	Canceled	Negligible	4

On 19 August 1940, The Surgeon General pointed out to The Adjutant General that a large proportion of early cases of pulmonary tuberculosis could be demonstrated only by X-ray (*11*). For this reason, he recommended that a survey be made of all military personnel to identify those with the disease and, further, that a method be developed to include chest X-ray as a routine part of the preinduction medical examination.

The Adjutant General, in his reply, granted the desirability of universal chest X-rays but did not consider it feasible to make the practice mandatory at this time. On 25 October 1940, however, he issued a directive to the commanding generals of all corps areas and departments to the effect that chest X-rays should be made on all Selective Service registrants when "underweight, pallor, abnormal chest findings, or suggestive personal or family history" pointed to an increased likelihood of pulmonary disease (*12*). It was

further directed that, when facilities were available and the practice would not retard the flow of registrants through induction stations. X-rays of the chest should be made routinely on all the men examined. If induction took place at other than Army stations, arrangements for chest X-rays should be made with state and civilian laboratories.

On 14 November 1940, The Adjutant General directed that medical facilities of other Federal agencies be utilized as far as practical in preinduction X-ray examinations of the chest. On 9 January 1941 (*13*), it was directed that X-ray examinations of the chest be part of the routine of examination for all voluntary enlistments and reenlistments in the Regular Army and the National Guard. The examinations were to be made at Army stations when facilities were available, and otherwise at the first station of assignment.

1941

On 3 June 1941, The Adjutant General directed that X-rays of the chest be routine in preinduction examinations for all Selective Service registrants, so as to "exclude from induction those with pulmonary tuberculosis and other significant intrathoracic defects (*14*)."

MOBILIZATION REGULATIONS

The new edition of "Standards of Physical Examination During Mobilization" (MR 1–9) that was issued on 31 August 1940 (*15*) contained many of the recommendations of various subcommittees and committees of the Division of Medical Sciences, NRC, including the Subcommittee on Tuberculosis. The same standards of physical examination during mobilization, prescribed by Executive Order No. 8570 and signed by the President on 18 October 1940, which were contained in these regulations, continued in effect throughout the war, though they were modified and reinterpreted in the regulations successively issued on 15 March 1942 (*16*); 15 October 1942 (*17*); and 19 April 1944 (*18*). The regulations of 15 March 1942 made the unqualified statement, "The chest examination will include a roentgenogram as well as the usual methods of physical examination."

Criteria of Rejection

During World War II and in the period of mobilization immediately before the United States entered the war, just as it had been in World War I, active pulmonary tuberculosis (fig. 33) of whatever degree and whether generalized or localized was an unqualified cause for rejection of the registrant, as was tuberculosis of the tracheobronchial lymph nodes. There were, however, certain lesions about which some discretion was permitted and about which there were some changes of opinion as the war progressed. They included:

FIGURE 33.—Moderately advanced pulmonary tuberculosis detected in routine roentgenogram of chest at induction center, a photoroentgen film of chest as originally produced on 4- x 5-inch film.

1. *Fibroid lesions.* These lesions were at first described as "small fibroid lesions," and later as "scarred fibroid or fibrocalcific infiltrative tuberculous lesions." Registrants with such lesions could be accepted tentatively if the infiltrative lesion did not exceed a total area of 5 square centimeters. They could be accepted without qualification if during a 6-month period the lesions did not progress or regress. Unless, however, the lesions had a sharply defined linear or nodular appearance on X-ray, the applicant was not accepted, even if the measurements were within the criteria specified and were stable over the 6-month period of observation. Much was left to the discretion of the examiner, who was warned that lesions in men under 25 years of age were more likely to be reactivated than similar lesions in subjects over this age. It was realized that 6 months was an undesirably short period of observation, but in the circumstances of war, a longer period was not considered practical. A man with cavitation was never accepted.

2. *Calcified lesions.* Theoretically, a competent examining physician, assisted by a competent radiologist, should have been able to determine the status of registrants with calcified pulmonary lesions, but practically, in the conditions that existed in induction stations, this was not true. Well-trained professional personnel were not always available. Rapid examination was necessary. Finally, all grades of calcification were encountered, from barely perceptible nodules to huge, incompletely calcified masses. Personnel serving at induction stations frankly confessed their inability to determine the status

of these lesions and asked for guidance from the Office of The Surgeon General. Colonel Hillman, in turn, asked the assistance of the Subcommittee on Tuberculosis, NRC, and a meeting to discuss the matter was held on 17 May 1941 (*19*).

At this meeting it was pointed out that the experience of the first 6 months of operation under the Selective Service Act indicated the necessity for arbitrary, rigid standards, and the decisions made were based on that necessity, although several of the members present objected to what seemed the subordination of clinical judgment to purely objective data.

The decisions arrived at represented a practical compromise. It was agreed that large lesions and numerous lesions were more likely to present hazards, since tubercle bacilli might remain viable in them and, under wartime circumstances, serve as a source for endogenous spread of the disease. It was therefore decided that men with calcified lesions could be accepted for service if (1) the residual lesions in intrathoracic lymph nodes did not exceed an arbitrary limit of 1.5 cm. (measured on a single 14- by 17-inch film) and (2) the total number present did not exceed 5. Those with calcified lesions of the pulmonary parenchyma could be accepted if the number of lesions present did not exceed 10. The diameter of any one of them might be, but must not exceed, 1 cm., but all of the others must be under 0.5 cm. in diameter. On the film, the lesions must appear isolated, sharply circumscribed, homogenous, and dense.

In many induction stations these criteria were applied with great rigidity, and so much criticism arose that they were slightly liberalized in MR 1–9, 15 October 1942 (*17*). The source of the difficulty, it was believed, was that examining physicians and radiologists had failed to use the "Standards of Physicial Examination During Mobilization" as "a guide to their discretion," not to be construed too strictly or too arbitrarily, as set forth in Section I. In the October 1942 regulations, therefore, a paragraph was added calling attention to this provision and stating that consideration be given to accepting registrants whose calcified lesions were apparently well healed, who were otherwise in good health, who had a favorable past history, and who were over 25 years of age. If necessary, the opinion of an expert in pulmonary conditions should be sought. MR 1–9, 19 April 1944 (*18*), repeated these criteria, pointing out that well-calcified masses in adult white subjects usually represented lesions that were entirely healed, but that partly caseous masses in younger subjects, particularly nonwhite subjects, were potentially hazardous.

There was no evidence during the war that calcified lesions were a significant source of morbidity, and the criteria employed during those years were continued afterward.

Pleurisy.—Pleurisy, particularly pleurisy with effusion, is recognized as possibly related to tuberculosis, and MR 1–9, 31 August 1940 (*15*), recognized this possibility and cautioned against it but did not definitely list pleurisy with effusion as a cause for rejection. The March and October 1942 issues of

MR 1–9 (*16*, *17*), however, were more specific, listing fibrinous or serofibrinous pleurisy of both tuberculous and unknown origin as disqualifying. Registrants with a previous history of pleurisy were to be studied with particular care, and those with chronic fibrous pleurisy of such a degree as to cause retraction of the chest wall and mediastinum were to be rejected, as were those whose roentgenograms showed densities sufficient to obscure completely a considerable section of the pulmonary markings.

These same issues of MR 1–9 and the April 1944 issue (*18*) stated that a registrant with an authenticated history of pleural effusion of unknown origin within 5 years of the examination should not be accepted. Similarly, a history of acute or subacute fibrinous pleurisy known to be nontuberculous in origin was also disqualifying until a final examination showed recovery without disqualifying sequelae.

Other pulmonary lesions.—Registrants with nontuberculous lesions of the chest were frequently aware of them, but in numerous instances they were first revealed by X-ray at the induction station. Specific instructions were given to reject registrants with spontaneous pneumothorax (fig. 34), chronic bronchitis, bronchiectasis, bronchial asthma, bullous and generalized pulmonary emphysema, cystic disease, silicosis, other forms of pulmonary fibrosis, abscess, mycotic disease, foreign bodies, and tumors of the lung and upper respiratory system. Many interesting and unusual anomalies were noted at the induction centers, and radiology played an important diagnostic role in all of them.

FACILITIES

The early induction stations were set up in National Guard armories, converted warehouses, and other buildings that could be utilized for the purpose. Radiologic equipment was set up according to the conditions. Eventually, better physical facilities were provided, in buildings specially constructed or reconstructed for the purpose. Water supplies for the X-ray departments were then greatly improved, and facilities were provided to dry films more rapidly.

A limited use was made of traveling teams sent out to examine registrants in concentrations near their homes, instead of having them come to the induction stations. Any building available was used, and some of them proved admirably suited for the necessary examinations. In one area, the fourth floor of a hospital was used, together with the hospital X-ray equipment. In another area, a state prison was used (fig. 35). An X-ray department was available here, and chest roentgenograms were made and were ready for interpretation before the examining team arrived.

METHODS

Up to 1940, the technique employed in mass surveys of the chest chiefly involved the roll paper method of Power X-Ray Products, Inc., Glen Cove,

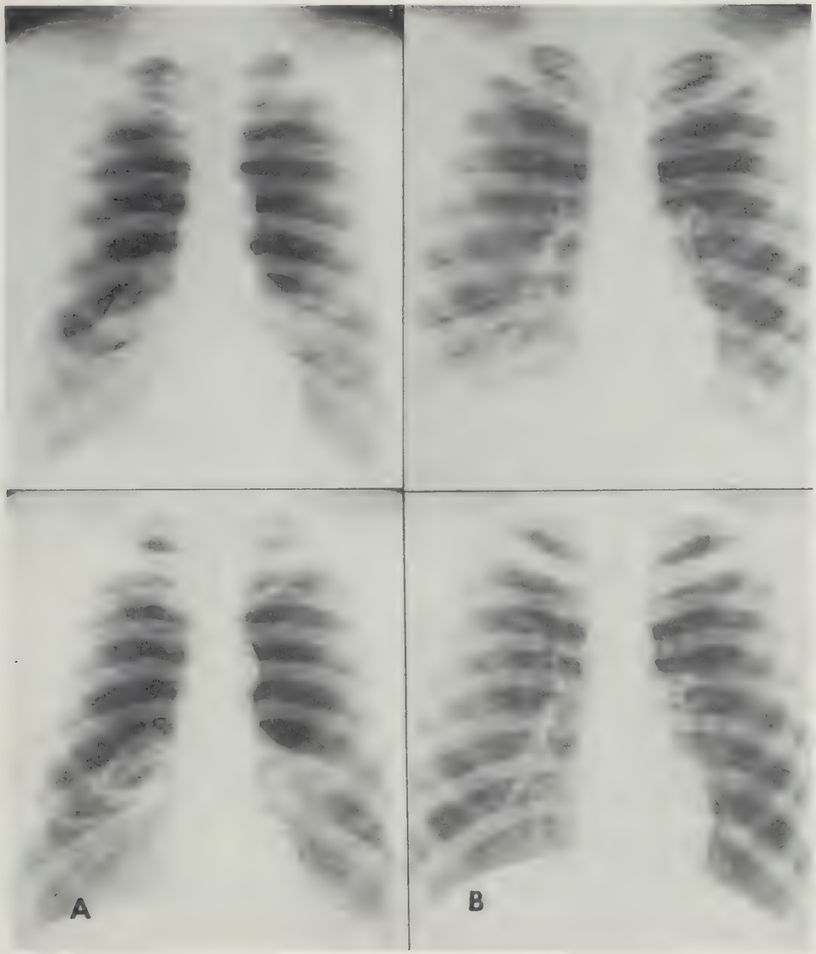

FIGURE 34.—Photoroentgen stereo films of chest produced on 4- by 10-inch films. A. Massive bilateral pneumothorax. B. Normal-appearing chest.

N.Y. (*20*). This technique had been used extensively in civilian surveys, in Civilian Conservation Camps, and in certain Army installations.

In 1939, just when the question of mass surveys in the Army was beginning to be seriously debated, de Abreu (*21*) introduced a method of fluorography (roentgen photography) by which a photograph of the fluoroscopic image of the chest could be made on a 35-mm. film. Lindberg (*22*) introduced a modification of the method. The following year, Potter and his associates (*23*), in collaboration with the General Electric X-Ray Corp., Chicago, Ill., introduced another method of photographing the fluoroscopic image of the chest, by a technique that involved the use of 4- by 5-inch films.

It was the last of these methods that was recommended by the board appointed by The Surgeon General in November 1939 when it made its report

FIGURE 35.—Induction station team in action, Illinois State Prison.

in August 1940 (*10*), after an exhaustive investigation of various techniques (table 2). The decision gave rise to arguments that were frequently acrimonious and that eventually reached the White House (*20*).

At a meeting of the Subcommittee on Tuberculosis, NRC, on 8 March 1941 (*24*), films of the same chests taken by each of the newly developed techniques were carefully examined. It was concluded that the large 14- by 17-inch films were far superior to the others in diagnostic detail and should be employed when possible. If they could not be used routinely, because of unavailability of equipment, expense, convenience of filing, or other reasons, then 4- by 5-inch films should be used.

On 9 April 1941, Major de Lorimier wrote Colonel Hillman (*25*) concerning the reasons for the decision to use 4- by 5-inch films for mass surveys of the chest in military personnel and registrants for Selective Service, forestalling the criticisms which he knew would shortly reach him. Colonel Hillman enclosed a letter written by him in reply to one of the multiple letters he had received in connection with this decision, in which he repeated the reasons that had guided the board appointed by The Surgeon General to investigate the whole question (*8*).

In his letter to Colonel Hillman, Major de Lorimier granted the shortcomings of the technique to date. The equipment was still inefficient in a number of respects, and the lens then in use meant "increased punishment of X-ray tubes." It was nonetheless his opinion that all of these difficulties could be overcome in time.

While criticisms of the use of this method continued until the end of the war, there was eventually general agreement that, considering the circumstances and necessities, no other plan could have achieved the desired results

(p. 111). It is interesting, too, that even the medical officers most critical of the decision of the board gave Major de Lorimier solid backing when they attended his course at the Army Medical School at Walter Reed General Hospital, Washington, D.C., and received instruction in the correct use of this technique. Dr. (formerly Lieutenant Colonel, MC) Frederick K. Herpel wrote in 1961:

> The writer early in 1942 became convinced that examination of the chest by the photoroentgen method was superior to the examination by flat film study. Many comparisons between photoroentgen films lead you to the inescapable conclusion that time and efficiency would be served by relying on the photoroentgenographic film findings alone, recommending rejection of inductees where indicated without time-consuming hospitalization and reference to already overworked base and station hospitals. I believe this was justified at the time, and that a review of the cases of tuberculosis which developed in the Army after induction will bear this out.

The first mass X-rays of the chest in induction stations had to be made with the equipment and films available, and for a time the Power roll paper films continued to be widely used. City and county health departments, units of the National Tuberculosis Association, and other organizations were extremely helpful in supplying equipment until the equipment for the new technique could be produced. By the spring of 1941, 45 induction stations were supplied with the necessary equipment, and by the end of the war practically every station was using photoroentgenography; 14- by 17-inch films were used for conventional X-ray study to supplement 4- by 5-inch films whenever the latter were not definitive.

The only difficulties that arose with any films occurred in certain parts of the South, when damage from excessive heat sometimes made them unusable.

EQUIPMENT

As Captain de Lorimier pointed out in the report of the board appointed by The Surgeon General in November 1939 (*10*), the problem was to provide a screening or case-finding procedure, not an essentially diagnostic procedure. For this purpose, small films were practical and efficient. Large film studies (stereoscopic, oblique, and lateral views) should be obtained whenever preliminary findings were in any way doubtful.

The screening procedure adopted (and variously termed reduction roentgenography, photofluorography, and photoroentgenography) was based upon recording photographically the image produced upon a fluoroscopic screen. With the candidate standing in front of the fluoroscopic screen and positioned in the conventional manner, the X-rays were directed through him and became effective upon the fluoroscopic screen. A lens or camera arrangement, incorporated on the fluorescent side of the screen and properly protected against extraneous light, provided for recording the image.

The apparatus required for this procedure consisted of:

1. A fluorescent screen, several types of which were available when the program was begun.

2. A lens with a uniform refractory power of approximately F 1.5. When lenses of slower refractory powers or speed were used, the exposure requirements were more than doubled, which meant that considerably greater punishment was inflicted upon the X-ray tube, whose life was concomitantly shorter.

3. Films of the smallest grain size possible, to enhance clarity of detail. Since recording of the fluorescent image was essentially a photographic and not a radiographic procedure, only the principles and practices of photography were involved. It was therefore the practice to use sensitized film with an emulsion coated only on one side of the transparent support rather than the duplitized film used conventionally in X-ray work. It was considered advisable, to meet the "requirements of almost automatic coordination with the other members of the technical examining team," to include on a single film the two projections made of each candidate. This plan had several advantages. It lessened possible confusion in the darkroom and prevented the bottleneck which could have occurred if the two exposures made of each man had to be matched with each other. The plan also saved the services of one technician.

4. A film holder, which, to provide for true stereoscopic projections, permitted automatic shifting of the film.

5. An X-ray unit of high milliamperage capacity, so that exposure time could be reduced to values whereby movements of the pulmonary vessels and voluntary movements would not introduce difficulties. Units of smaller milliamperages could be used and were, but with them the exposure time had to be increased.

The most desirable tube was a stationary anode tube, with an effective focal spot dimension of not less than 5 mm. square as projected. Since it was necessary to make two exposures per minute, a tube of smaller focal spot dimensions could not be expected to withstand the rapidity of the heavy loads required, particularly when stereoscopic pairs were to be obtained.

The standard U.S. Army portable grid was satisfactory. With it, it was merely necessary to increase the milliampere-second value to twice that which would be used without it, though this technique meant a considerable increase in the punishment of the X-ray tube. The use of a grid was considered necessary only in candidates with chest measurements of 23 cm. or more.

6. Standard film processing equipment, to provide for the use of large roentgenograms when they were indicated. The time-temperature method of processing was recommended, to insure uniformity of results.

PERSONNEL AND TRAINING

Officers.—Once routine X-ray examinations in induction stations were decided upon, the problem of personnel and their training arose. The task of interpreting the films was not, of course, as simple a matter as some of the discussion concerning it might suggest. Until enough Army personnel could

be secured, radiologists in induction stations frequently consisted of local personnel who worked part time, usually part of the day for a certain number of days each month. Some of these radiologists were distinguished members of the profession. In Baltimore, Md., films were interpreted by a group of radiologists selected by the Committee on Medical Defense of the Medical and Chirurgical Faculty of Medicine at the University of Maryland School of Medicine, and other plans were used in other large cities. In smaller communities, the responsibility could be carried by one or two civilian radiologists. The Subcommittee on Tuberculosis, NRC, furnished the Office of The Surgeon General with lists of qualified experts in tuberculosis, graded in four categories on an arbitrary scale, and the lists were distributed to corps area commanders according to localities.

The Army personnel who eventually staffed most of the induction centers were young radiologists recently out of training, or still in training, or men without any radiologic training who had accepted commissions in the Reserve on graduation. The American Board of Radiology permitted those called up before completion of their residency to obtain credit for up to a year of their military service.

Most of these radiologists were trained in the Army School of Roentgenology, at first at Walter Reed General Hospital and later at Memphis, Tenn. (p. 30), under Colonel de Lorimier. For officers with good radiologic training, the course was limited to 2 to 12 weeks, but the training was conducted so vigorously that a great deal was accomplished. Courses were longer for radiologists with little or no training. Many of the men trained in these courses remained at the induction centers in the Zone of Interior for 2 and 3 years, and there was general testimony to the excellence of their work.

During their training, the medical officers were taught the use of 4- by 5-inch films and the equipment for them, as well as the standards of interpretation in MR 1–9, War Department TM (Technical Manual) 12–221 (*26*), and other Army and civilian publications. One of the most useful of these publications was "Diagnostic Standards and Classification of Tuberculosis," published by the National Tuberculosis Association (*27*).

When Colonel Long was appointed Chief, Tuberculosis Section, Office of The Surgeon General, in July 1942, he spent a considerable part of his time in visits to induction stations and in coordinating the work in this field. His visits proved highly effective in improving X-ray examinations and the interpretation of films. The atlas on chest radiology (*28*) which he was instrumental in producing was an extremely useful publication; it contained examples of every lesion mentioned in the section on lungs and chest wall in MR 1–9.

The turnover of military roentgenologists later in the war made it difficult to maintain consistently high standards of interpretation of films, especially after V–E Day and V–J Day, when the work was done by officers who were assigned to separation centers and about to be separated themselves (p. 115).

Technicians.—Enlisted technicians were an essential part of the operation of X-ray sections in induction centers, and the turnover among them was always a problem. Eventually, some limited service personnel were trained for this work and proved very satisfactory. Until then, radiologic teams were constantly losing physically fit, well-trained technicians for oversea service. Before the war ended, civilian personnel were also employed in many induction centers.

Induction station X-ray sections were originally set up, as already mentioned, to handle only chest work. Those who needed X-rays of the gastrointestinal tract, spine, skull, and other parts of the body were sent to other Federal facilities or to civilian clinics. Radiologists assigned to these stations therefore had the onerous task of examining chest films, and nothing but chest films, for many hours each day. The monotony of their work was their chief complaint, as a number of personal accounts indicate (p. 115).

RADIOLOGIC ROUTINE

While the routine of examination varied from induction station to induction station, most preferred to have the chest X-ray taken as the first, or almost the first, procedure, so that the films would be ready for interpretation by the time the registrant had completed the remainder of his examination. There had been no previous X-ray examination at the Selective Service Board. Registrants were examined there, but only to weed out those with obvious deformities or advanced diseases, who could not possibly be considered for military service. Those sent to induction centers were presumably fit for service. The preliminary screening by the local board was reasonably accurate early in the war. Later, when the demands for manpower grew increasingly urgent, it ceased to be of value because the boards began to send to the induction stations personnel who could not possibly be considered for service (fig. 34). It was not uncommon for men to arrive in wheelchairs, and at least one induction station reported examining a man in the third stage of silicotuberculosis with such dyspnea it was difficult to secure a satisfactory radiograph of his chest.

Examination of registrants was on an assembly line basis; the numbers permitted nothing else. The usual routine called for 50 radiographs per hour, and 300 per day was considered an optimum load. When the calls were urgent, however, more than 500 stereoscopic films were made per day, and occasionally a thousand exposures were recorded. In the larger induction centers, several X-ray units were often operated at the same time.

It was considered desirable to read dry rather than wet films, and many ingenious plans were instituted to reduce the drying time. Wet films were never examined stereoscopically. It was not considered mandatory that films be studied by third-dimensional projection, but it was considered highly important that the tube be shifted between the two exposures, in order to

reveal the topographical relations of any suspicious densities that might be visualized.

Handling of Films

The processing of the X-rays was regarded as the critical part of the procedure, since films were to become part of the man's permanent record. The aim was to process them so that they would be available for at least 40 years. Since poorly washed films are likely to turn brown within 6 months, information on proper methods of processing was continuously disseminated during the war.

The method of identifying films and the container in which they were placed was standard in all induction stations (fig. 36). All of the data were on the film when the exposure was made and all that was necessary later was the addition of the serial number.

By previous agreement with the Medical Director of the VA (Veterans' Administration), films made on induction of all personnel, as well as the films made on their discharge (p. 114), were sent to the VA where they were filed serially by Army serial number (*29*). These films eventually constituted the largest collection of the kind in the world.

The VA depository has proved its worth since the war. On numerous occasions, the use of these films has supplemented studies made of pulmonary disease in civilian life. Private physicians have also found these films most useful in comparative studies of their patients. The routine of procurement was at first somewhat slow and cumbersome, but later became swift and efficient.

Rejections and deferments.—At the beginning of the X-ray program, the films of individuals who had been rejected (and about whose rejection there was no question) were sent to the State headquarters of Selective Service. Films of men deferred for borderline conditions were retained at Army examining stations for comparison with films to be made later. In practice, this plan did not work very well, and the plan was then adopted of sending these films back to local boards, where they were held until the registrant returned for further examination.

CRITIQUE OF PROGRAM

Estimates vary as to the number of persons who underwent radiographic examination of the chest in the Zone of Interior during World War II. Exact figures are not available. In September 1941, it was estimated from a survey that had been made that 50 percent of the men inducted into the Army up to 1 March 1941 had had chest X-rays (*30*). Col. Arden Freer, MC, in 1944, set it at 10 percent of the total population of the country (*31*). Dr. Long set it at 20 million persons, his estimate including Army enlistment stations and the joint Army-Navy induction stations (*3*).

The program, of course, was not all inclusive. For a variety of reasons,

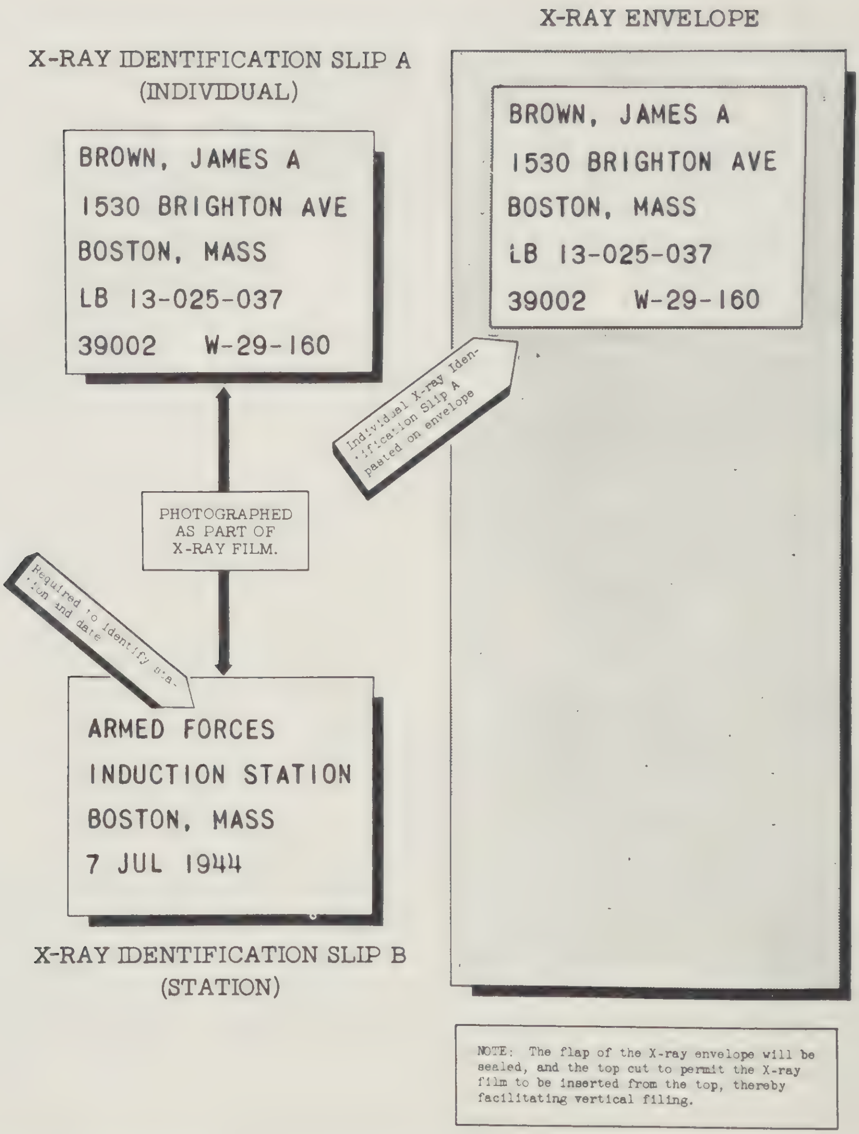

FIGURE 36.—Method of identifying individual films and film containers at induction stations (*26*).

chiefly lack of proper equipment and personnel, the percentage of examinations varied widely in different corps areas early in the war, though after the first of April 1942, very few candidates for induction escaped examination. Dr. Long estimated that perhaps a million enlisted men were accepted for service without chest X-rays, though many—perhaps most—of these were later examined at reception or basic training centers.

In World War I, when, as already noted, exclusion from service was based almost entirely on the results of physical examination, the rejection rate for tuberculosis, actual or suspected, among men examined by local boards and at camps was 2.3 percent. In World War II, when exclusion was chiefly on roentgenographic evidence, it averaged less than 1 percent during the entire period of mobilization. In World War I, tuberculosis led the list of causes of separations for disability, accounting for 11.1 percent of the total number and 13.5 percent of the separations due to disease. In World War II, it accounted for only 1.9 percent of all discharges for disability from disease. The decrease is to be explained in part by the lowered incidence of tuberculosis when the United States entered World War II, but it is chiefly to be explained by the greatly improved procedure of excluding candidates at induction centers (*3*).

The reliance on X-ray examination in World War II is in striking contrast to the low estate in which this modality was held during World War I. Matson's comment was typical (*32*): "As compared with the physical examination, the roentgenological examination, even when done by an expert, occupies a place of secondary importance in the diagnosis of tuberculosis of clinical significance."

The principal criticism of routine X-ray examination in World War II was that too much reliance was placed upon it. Myers (*33*), one of the critics of the program, considered it a major error not to have employed tuberculin tests also. Theoretically, the criticism is perhaps sound. Practically, it would have been impossible to employ this test in the conditions in which men passed through the induction stations. It would have been necessary, in addition to the time required to read the tests, to hold possibly 4 million men with positive tests for special observation, re-X-rays, and other procedures that would have choked the channels of induction and further complicated procedures at separation centers after the war.

There were undoubtedly errors of both acceptance and rejection to be charged against the X-ray program. Certain postwar investigations (*34*) show that about half of the men discharged for tuberculosis in the course of the war had the disease in a radiographically detectable form when they were accepted for service and that their lesions had been overlooked in error. Presumably, some of the remaining men who were discharged had old lesions, not detectable by X-ray, which broke down under the strain of military service. This study bore out a fact recognized when the program was instituted, that a certain human fallibility in the interpretation of films will always occur; radiologists do not always agree with each other, nor on rereading the same films after intervals do they always agree with themselves.

The principal error of the X-ray program was that too many men with lesions of doubtful stability were accepted. On the other hand, probably too many were rejected for lesions visible in films but clinically of no consequence. The error in this respect was generally considered excusable in view of the uncertain prognosis of infiltrative (calcified) lesions in young men. The

regional differences in rejections for these lesions became clearer when postwar studies suggested that histoplasmosis rather than pulmonary tuberculosis might have been responsible for a certain percentage of them (*35*).

The imperfections and possible risks of mass X-ray survey of the chest in candidates for the Armed Forces was fully recognized when the program was instituted. Quite aside from the defects inherent in the technique employed, errors were due to the necessity for speed; the constant shortages of fully qualified personnel; and the fatigue incident to overwork in crowded induction stations. On the other hand, the screening method adopted was the only one practical under the program instituted by the Medical Department. It eliminated the majority of active cases of tuberculosis and provided a body of troops as nearly free from the disease as was possible in the circumstances.

It should be pointed out again that the X-ray survey of candidates for induction demonstrated pulmonary diseases other than tuberculosis and abnormalities and on several occasions revealed metastatic pulmonary lesions from primary malignancies not previously recognized.

SEPARATION CENTERS

To complete the record, a few words might be said about the role of X-ray examination in separation centers, though the story is much the same as it was in induction centers. In many instances, in fact, the separation centers were in the same location as induction centers, the facilities of which were simply transferred to the new mission.

Even before the United States entered World War II, provision had been made, in July 1941, for roentgenography as part of the terminal examination of both officers and enlisted men. The precise procedures were later outlined in other War Department publications (TM 8–255, 10 September 1945 (*36*); and TM 12–222, 15 October 1944 and 20 September 1945 (*37*)). The examinations were to be made on stereoscopic films 4- by 5-inch, and larger films (14- by 17-inch) were to be used if the smaller films were not fully diagnostic.

Whenever borderline lesions were discovered, in which stability could not be determined clinically and radiologically, the men were sent to hospitals for observation, and the films made on their induction were obtained from the VA files and studied comparatively. This practice was of great value, particularly when the routine began to operate so smoothly that no time was lost in the procurement of the earlier films.

Further details of the disposition of men with chest lesions discovered in separation centers are not part of the story of radiology in World War II; but it might be mentioned that, though the majority of the lesions were minimal and the numbers of men involved were not great, the VA was not then prepared to handle the patients and the Army had to expand its facilities to take care of them.

Unfortunately, many of the errors made at induction centers early in the war were repeated at separation centers after the war was over, and for the

same reasons, the need for haste and the shortages of qualified personnel to handle the workload. Dr. (formerly Lieutenant Colonel, MC) Dionisie M. Sirca recollected in 1961 that at Camp McCoy, Wis., as many as 3,300 men were sometimes processed each 24 hours, and the four radiologists who were on duty worked from 8 o'clock in the morning until the work was finished, which was often late at night. In other separation centers, processing was conducted in three shifts, around the clock, which required radiologists to be on duty around the clock; because of shortages of personnel, an 8-hour shift on duty was often extended to 12 hours and sometimes more.

Another reason for errors has already been mentioned, that radiologists who were handling the examinations were many of them due for prompt separation themselves. The result was frequent changes of personnel, and, regrettably, a frequent lack of interest in anything but their own separation.

If a similar situation should arise in the future, provision should be made for better control of such centers, and the radiologic department should be staffed, as the World War II separation centers usually were not, for the maximum workloads likely to be encountered.

X-ray service necessary at ports of embarkation was usually provided by adjacent station or general hospitals. The Station Hospital, Fort Hamilton, Brooklyn, N.Y., for instance, served the New York Port of Embarkation in this capacity, and the same situation prevailed at other ports of embarkation.

SPECIAL EXPERIENCES

Service at induction centers always had elements of monotony, but the work had to be done, and medical officers who took advantage of their opportunities derived positive values from it, as the following summarized experiences show:

Dr. (formerly Major, MC) Burton L. Williams wrote in 1961:

I served at Fort Bragg, N.C., for about a year, approximately half of which was spent at the induction and separation center. There were usually four or five of us on this duty. The others, like myself, were on 8-hour shifts and rotated through both day and night. The films were all photofluorograms on the selectees. They were read wet and I'm sure were subject to many errors. We did approximately 100 of these an hour. The films of the inductees and officers being separated were on 14- x 17-inch films and were read dry. There were about 300 of these and there should have been very little error in this group. I would say that this was the low point of my Army career. None of the radiologists were pleased with the tremendous number of wet readings and all of us felt that normal errors were unavoidable.

Dr. (formerly Lieutenant Colonel, MC) Richard Schatzki, also in 1961, wrote as follows:

I spent 3 months in the induction station at Wilkes-Barre, Pa., and another 3 months at the induction station at Baltimore. In both places, civilian radiologists had appointments to read films although an Army radiologist was present full time at the stations. In other words, I found myself confronted with a large number of civilian consultants, some of them excellent, others not so good. If I had intended to—and apparently some of my predecessors did so—I could have confined myself to the supervision of the adminis-

trative aspects of the station. For this, someone with radiological knowledge would not have been necessary. On the other hand, as soon as I started to work actively at these stations the consultants really became superfluous. I believe that there are two ways in which this could be handled in the future. There could either be an Army radiologist at the station, who would run the station administratively and professionally, or if not enough Army radiologists should be available for such an arrangement, the civilian radiologist could do the professional work and the nonradiological officer could run the administrative side. The assignment to such an induction station is professionally obviously not so desirable as one to a hospital. However, it need not be quite so boring as it might appear. A younger man may learn quite a bit about the broad spectrum of normal variations. I have even found that one does not have to be really that young in radiology to get a certain stimulation from such a cross section examination of the population.

Finally, Dr. (formerly Colonel, MC) Joseph Levitin, again in 1961, wrote:

I, as a major in the Medical Reserve, was called to active duty the 17th of December, 1941, and assigned to recruiting and inductive service, Ninth Corps Area. This was located in San Francisco, which was also the headquarters of the Ninth Corps Area. This was to be a temporary assignment and I was to establish a photoroentgen unit which was to be installed in all the induction stations. At the time I reported, physical examinations for induction were taking place at the State armory, but plans were already underway for the moving to a central location of their own. Until the photoroentgen equipment arrived, chest X-rays were being made in private laboratories. Arrangements had been made with private radiologists to take chest films on the inductees. Fifteen to twenty men at a time were transported by truck (supplied by the Quartermaster Corps) to the various private offices. Reports were submitted that day.

I busied myself with plans of the new installation, although information as to what to expect was minimal * * *. In the new installation, it was decided that the inductees would first visit the laboratory, leave a specimen of urine, have their blood drawn, then have the chest X-ray. From there they would proceed along the usual routine of their physical examination. By the time they arrived for the final evaluation, the chest films would be processed and I would read them wet unless further study was needed.

In the construction of the X-ray room, no provision was made for insulating the radiographic room. No lead for the walls was included in the construction plans. The Ninth Corps Area Headquarters was still in San Francisco, but was in the process of moving to Salt Lake City. There was nobody at Ninth Corps Area aware of the problem of the installation of radiographic equipment. After being turned down by Medical Supply, and by the Quartermaster (as an item, lead was not on their list), I finally landed at Engineer Corps. There I was told to go ahead and purchase some lead on the market and submit the bill to the surgeon of the Ninth Corps Area. Fortunately, I had been in private practice in San Francisco and had had the experience of installing X-ray equipment in my own office and hospitals and I knew at once where it could be purchased, so without further delay the walls were properly leaded * * *.

When the equipment arrived, we had a General Electric photoroentgen unit, a Picker tube stand, a Westinghouse transformer, and a Machlett tube. There were about a dozen hangers of a slot type, the type used with lantern slides, which would hold three 4 x 5 films. Our films were taken stereo, with two exposures to a 4 x 10 film. There was no dryer.

The greatest problem we had was the wear on the tube. Even though we kept within the ratings of the tube the heat dissipation was not rapid enough. A rotating anode tube was required. We were processing up to 400 men a day and completing the examination by 1:00 P.M. At the rate we were going the tube would not last for 10,000 exposures and more likely only 5,000. I wrote to the surgeon of the Ninth Corps

Area requesting a rotating anode tube and brought the situation to my commanding officer. The train left for the reception center at Monterey at 1:00 P.M. If the men were not processed in time for that train it meant a hotel room and two meals in San Francisco, which was a greater cost than a new tube per day. It was decided to rush the processing through and replace X-ray tubes.

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CHAPTER VI

Named General Hospitals in the Zone of Interior

A. Bradley Soule, M.D., and *Benjamin Copleman, M.D.*

Section I. Administrative Considerations

GENERAL CONSIDERATIONS

The history of radiology in the named general hospitals in the Zone of Interior during World War II has not been easy to prepare. Annual reports were required from all these hospitals, it is true, but it is perhaps a tribute to the taken-for-granted excellence of the radiologic service in them that in many respects the account of the service in the reports was almost perfunctory. Many times, the report of the succeeding year was little more than a repetition of the report of the preceding year.

Complimentary as this situation may be to radiology, it is not conducive to the preparation of a detailed history. In addition, the death of Col. Byrl R. Kirklin, MC, Consultant in Radiology, Office of The Surgeon General, while this volume was still in the planning stage, removed an invaluable source of information on general hospitals in the Zone of Interior (and on a great many other subjects). It has been possible for the authors of this chapter to prepare it only because of the generous help they received from many of their confreres who served in these hospitals during the war and who took the time to search out their personal papers and to write their personal recollections. Their names are listed elsewhere (p. xxiii).

By Army regulations, general hospitals had the mission of studying, observing, and treating the more obscure and complicated cases. The mission of their departments of radiology is implicit in that statement. It would not be possible to care for such patients without the aid of diagnostic radiology.

The 66 general hospitals in the Zone of Interior during World War II operated for varying periods of time (*1*). Barnes General Hospital, Vancouver, Wash., received its first patient on 16 April 1941, 8 months before the United States entered the war, and disposed of its last patient on 14 December 1945. Ream General Hospital, Palm Beach, Fla., became operational on 10 September 1943 and received its last patient on 21 July 1944. It had been an Army Air Forces station hospital before it began to operate as a general hospital. A few other general hospitals had also served as Army Air Forces

station hospitals. Four general hospitals served camps in the Zone of Interior: U.S. Army General Hospital, Camp Butner, N.C., U.S. Army General Hospital, Camp Carson, Colo., U.S. Army General Hospital, Camp Edwards, Mass., and U.S. Army General Hospital, Camp Pickett, Va. These hospitals, formerly Army Service Forces station hospitals, began to function as general hospitals on 30 January 1945, and all reverted to the camps they were serving between December 1945 and April 1946.

The bed capacity of the named general hospitals in the Zone of Interior ranged from 921 beds at Darnall General Hospital, Danville, Ky., to 5,350 beds at Halloran General Hospital on Staten Island, N.Y.

Practically every general hospital served as a center for one or more specialties. Kennedy General Hospital, Memphis, Tenn., served as a center for neurology, general and orthopedic surgery, thoracic surgery, neurosurgery, and psychiatry. Halloran General Hospital served as a center for neurology, general and orthopedic surgery, and neurosurgery, and several hundred patients were under definitive specialized treatment there at all times. Its principal function, however, was the reception of casualties from overseas, who were retained only long enough for triage, to be certain that they were in condition to be moved to other hospitals throughout the country for further care. DeWitt General Hospital, Auburn, Calif., which was a center for general medicine, neurology, neurosurgery, vascular surgery, and psychiatry, made, at the peak of its operation, from 3,000 to 3,600 diagnostic roentgenograms per month and had from 700 to 800 orthopedic patients in its wards at all times. The hospital at Camp Forrest, Tullahoma, Tenn., Prisoner of War Hospital No. 2, was, as its name implies, operated entirely for prisoners of war. It was formerly an Army Service Forces station hospital. It had a bed capacity of 2,500 and operated from 21 October 1944 to 15 December 1945.

It must also be remembered that, while most of the population of the general hospitals in the Zone of Interior was military, some of these installations also served dependents of officers and servicemen, maternity patients, and retired officers and their wives and dependents. The ages of the patients thus ranged from pediatric to geriatric. Walter Reed General Hospital, Washington, D.C., had a notably wide range of patients.

The organization of the radiologic department in any general hospital depended upon the volume of its work and its specialized mission. The services which radiology was called upon to supply are obvious in the statements just made about general hospitals and will be pointed out in detail later in this chapter.

General hospitals in the Zone of Interior had opportunities for special studies and research projects which were difficult or actually impossible in general hospitals overseas. These studies are also discussed later in this chapter (p. 166).

ORGANIZATION AND ROUTINE

In most general hospitals, at the beginning of U.S. participation in World War II, the X-ray department was a subsection of the surgical service. In many hospitals, before the war ended, it was a separate service, reporting directly to the commanding officer.

In newly constructed hospitals, radiologic personnel had to develop their own organization and routine. In hospitals which had previously operated, the existing organization could usually be continued, though often with some modifications. In an occasional hospital, such as Walter Reed General Hospital, organization and routines were so efficient that practically no modification was necessary in them during the entire war, beyond such changes as were required by the increasing workload. Col. William LeR. Thompson, MC, had been chief of the radiologic service until September 1942, when he was succeeded by Maj. (later Lt. Col.) Aubrey O. Hampton, MC.

Each hospital devised its own working routine, based upon requisitions sent in the day before the examination was desired. The requisition on standard form WD MD 55K, Radiologic Report, specified the part of the body to be examined and the provisional diagnosis. Emergency and bedside examinations were clearly indicated. Films were numbered in sequence. A simple daybook was kept, which contained essential data (usually the patient's serial number and name, the type of examination, the provisional diagnosis, the number of films used and their size, and special notes when they were warranted). Reports and films were filed by whatever plan the individual hospital devised. Films were usually filed numerically and reports, by the patient's serial number or name or, occasionally, under both categories.

Many hospitals made it a practice to keep special records of interesting or unusual cases, for use at conferences, for later analyses, or for other reasons. Such a record, handwritten, was carefully kept at Walter Reed General Hospital, and the book in which the material was entered had become of great value when it disappeared, whether by careless handling or pilferage was never discovered.

It was most important, from every standpoint, that when special examinations were ordered, such as gastrointestinal studies, barium enemas, and cholecystograms and similar procedures, the patients should be properly prepared for them. Each ward officer was provided with the precise details to be followed for each study. As a rule, the routine of preparation was essentially the same as that used in civilian departments of radiology. The instructions used at Bruns General Hospital, Santa Fe, N.Mex., were incorporated in the "Professional Manual" adapted for use there by Maj. George J. Kastler, MC, Chief, Medical Service, from the standing operating procedures used at Lovell General Hospital, Ayers, Mass.

The efficiency of an X-ray department was largely judged by the speed with which it produced films and reported them. At Thayer General Hospital, Nashville, Tenn., the chief of the service, Maj. Joseph McK. Ivie, MC, required

that films be read three times daily and that the dictation be given directly to the typist. This plan permitted the majority of reports to be placed on the patients' charts the day of the examination, thus expediting their treatment and, in turn, expediting the turnover of hospital beds. It required, however, what a good many hospitals did not have, typists capable of taking dictation directly on the machine.

PERSONNEL

Medical Officers

The subject of radiologic officers is fully covered elsewhere in this volume (p. 19) and not much need be said about it in this chapter.

The chiefs of service in named general hospitals in the Zone of Interior were usually qualified radiologists, many of them teachers in medical schools and most of them already certified by the American Board of Radiology. The others had sufficient, or almost sufficient, qualifications for certification. It was entirely logical that well-qualified men should head these radiologic services, for, as already pointed out, the most difficult and most obscure cases found their way to general hospitals, particularly to those in which multiple specialty centers were located. Each named general hospital was by its very nature a center for diagnostic radiology. Moreover, all specialty centers were cooperative endeavors. Their success was in large measure due to that fact, and in all of them, there was obvious need for skilled radiologic service.

A few of the smaller general hospitals had only one radiologist. The larger hospitals had two or, occasionally, three, though the assistants were frequently less well trained than the chief and were occasionally officers who, with little or no radiologic experience, were, however, able to work competently under proper supervision.

It was not possible, of course, particularly as the war progressed and the need for radiologists increased, to permit officers to select their own assignments, but the staffing of the service at Walter Reed General Hospital presents an interesting illustration of how far, when circumstances permitted, the Office of The Surgeon General would go to secure radiologists of the highest standing and experience. Dr. Hampton, Radiologist in Chief at Massachusetts General Hospital, Boston, and Associate in Radiology at the Harvard Medical School, was eager to volunteer for service, but neither the hospital nor the school would release him unless he were given rank and position equivalent to his civilian rank and position. The Surgeon General initiated the fulfillment of these requirements by offering him a colonelcy and the position of Chief, Radiology Service, Walter Reed General Hospital. He was also given the privilege of choosing his assistant. He named for this position Capt. George M. Wyatt, MC, also a diplomate of the American Board of Radiology. The workload at this hospital was always heavy, and during most of the war, the

diagnostic X-ray section operated with 3 radiologists, 18 noncommissioned and enlisted technicians, a civilian stenographer, and 4 civilian file clerks.

In a few of the general hospitals in the Zone of Interior, Medical Administrative Corps officers were assigned to X-ray services and were able to handle a great deal of the routine of administration, leaving the chief of service more time for his professional responsibilities.

Circumstances at times militated against the most efficient use of both personnel and equipment. At Tilton General Hospital, Wrightstown, N.J., for instance, two radiology sections were operated, one at the hospital proper and the other at Fort Dix, a mile away. Both departments were well equipped, but the division required more personnel than a single service would have required.

Enlisted Personnel

In hospitals of the Zone of Interior, as in hospitals overseas, enlisted technicians performed invaluable work both qualitatively and quantitatively. At Fitzsimons General Hospital in Denver, Colo., for instance, seven enlisted and seven civilian technicians carried out 61,303 examinations in 1945. The training of technicians is discussed in detail elsewhere (p. 40), but it should be pointed out here that many technicians who assumed their duties after only limited theoretical training, and with little or no practical experience, by energy and devotion developed into highly competent personnel. More than one hospital report mentioned that, as time passed, a greatly increased workload was carried by fewer technicians than had been required for smaller loads, the explanation being increased experience, hard work, long hours, and the men's desire to do their part in helping to win the war.

Radiology departments in general hospitals had to provide 24-hour service, and night and Sunday calls were always the responsibility of enlisted personnel, since civil service, under which all civilian employees worked, made no provision for on-call status. This problem was nicely solved at Battey General Hospital, Rome, Ga., and Halloran General Hospital, where Seventh Day Adventists, who for religious reasons wished to be off duty on Saturdays, willingly took over the Sunday duties.

Technicians were always in short supply, and many competent men were lost to named general hospitals in the Zone of Interior when they received oversea assignments. In the early days of the war, enlisted men were replaced by Wacs. Later, as Wacs were also sent overseas, the departments were largely manned by civilians and enlisted personnel who had been physically disqualified for oversea service. In 1944 and 1945, a number of enlisted men and Wacs, returned from overseas, were assigned to radiology services in Zone of Interior general hospitals. Prisoners of war were often utilized as darkroom technicians and for other duties that did not involve handling U.S. Army patients (p. 148).

Technicians were usually permitted to remain in the positions for which they had been trained, but there were occasional exceptions. In December

1944, when a complete X-ray department was opened at Edgewood, 2 miles from Mason General Hospital, Brentwood, Long Island, N.Y., the need for technicians was considerably increased. This hospital, however, served as a debarkation center for neuropsychiatric casualties entering the port of New York, and so many of these patients required personal escort that it was frequently necessary to use X-ray technicians for this purpose. At times, as a result, the X-ray service was so undermanned that it had to be closed for all except emergency work. The situation was paradoxical: The larger the number of patients admitted to the hospital, the less work could be done in the X-ray department because its technicians were on escort detail. At the same time, the need for radiologic services was increased because many of the returning casualties also required definitive care. The dilemma was unresolved when the war in Europe ended.

Experienced Regular Army enlisted personnel were also of great help to newly inducted radiologic officers. When Colonel Hampton and Captain Wyatt assumed their duties at Walter Reed General Hospital, the only Regular Army technician in the department was Sgt. Walter P. Miller, who had worked for some time under Colonel Thompson, the former chief of the X-ray Section. Sergeant Miller served as head technician, instructing the rest of the technical staff, enlisted men, and Wacs, most of whom had had no previous technical experience. He also handled the paperwork and initiated his new superiors, who were totally inexperienced in Army matters, in the administrative side of their duties. Captain Wyatt, in 1960, wrote of the assistance Sergeant Miller had furnished him (Captain Wyatt) in his capacity as property officer, with the responsibility for close to $200,000 of Government-issue property: The day before Captain Wyatt was separated from service, the property inventory was short only one bucket, and Sergeant Miller found that early next morning.

Civilian Personnel

Before the war ended, there was scarcely a general hospital in which civilian employees were not working as technicians as well as clerical and secretarial personnel, who were required in large numbers in all X-ray departments. At Fitzsimons General Hospital, for instance, in 1945, there were 7 civilian technicians and 11 civilian typists and clerks.

Of inestimable value in many of the named general hospitals were the volunteer workers, such as the Gray Ladies and the nurses' aides supplied by the American Red Cross and other organizations. At Walter Reed General Hospital, where most of the Gray Ladies were wives of officers, their devoted, intelligent, and interested service resulted in an appreciable saving of manpower. Nurses were not assigned to the diagnostic section of the X-ray service. Nurses' aides, however, assisted in some gastrointestinal examinations of all female patients and provided other help of a nontechnical nature. One of them, Mrs. Carl Pforzheimer, worked many hours in the fluoroscopic room and developed such split-second timing in passing spot-film cassettes to the

radiologists that some of the Army line officers examined commented that she would have made a good member of a guncrew.

TRAINING

Medical Officers

When the Army School of Roentgenology was located at Walter Reed General Hospital (p. 26), Captain Wyatt and Capt. (later Lt. Col.) Charles L. Hinkel, MC, assisted with some of the teaching and found it, Captain Wyatt recalls, a most stimulating experience. When the school was moved to Memphis, the loss of this stimulus was keenly felt, Captain Wyatt comments, and was the only really serious deficiency in the operation of the radiologic service. In his opinion, the young officers assigned to the X-ray service were deprived, by the relocation of the school, of experiences by which they might well have profited, in view of the wealth of teaching material and teaching talent available. The diagnostic load, moreover, was so heavy that while student officers were gaining practical experience they could also have been very helpful in the department.

Radiologic training was available at medical schools located near general hospitals. Halloran General Hospital was particularly fortunate in this respect because of its location in a borough of New York City. Advanced training was also given at a number of general hospitals, including Bushnell General Hospital, Brigham City, Utah, Lawson General Hospital, Atlanta, Ga., McGuire General Hospital, Richmond, Va., Schick General Hospital, Clinton, Iowa, and Thayer General Hospital. Medical Department technicians schools were in operation at some of these hospitals, and the school instructors were most cooperative. The number of officers who received training at them was quite large. For example, 12 were trained at Lawson General Hospital in 1942, and 18 were trained at Schick General Hospital in 1944.

When hospital units destined for oversea service were stationed on the post with general hospitals, their indoctrination for oversea duties was part of the teaching function of the general hospital. The training was most successful when, as at Bushnell General Hospital, officer personnel were, in effect, made an integral part of the department activities.

Practices in regard to radiologists in replacement pools differed from hospital to hospital. In some hospitals, officers were made an integral part of the X-ray service, though, since most of them had not had adequate previous training, they were, at least in the beginning, a hindrance rather than a help on a busy service. At O'Reilly General Hospital, Springfield, Mo., for instance, only 2 of the 11 officers assigned to the X-ray department from the replacement pool had had sufficient previous training to be of any radiologic help. At some hospitals, officers assigned to the X-ray service for training simply observed.

At Lovell General Hospital, replacement pools contained large numbers of officers in 1942–43, when they were awaiting assignment, and later in the

war, when they were returning from oversea duties. It was the practice of the X-ray service to offer work to the officers who wanted it. Many of them did not: Early in the war, a number of them had just left busy private practices and preferred to relax. Later, when they had returned from overseas, some did not want work either, because reunion with their families and preparations for return to civilian life were of greater interest.

Technicians

In all hospitals, enlisted technicians received a great deal of informal on-the-job training. At DeWitt General Hospital in 1944, the radiologic personnel gave 3,842 hours of this kind of training to enlisted personnel and to some civilian personnel. At Schick General Hospital in 1943, 29 technicians, including 7 without previous X-ray technical experience, were trained, or given additional training, for the 8th and 91st General Hospitals temporarily on the post. The training included lectures, demonstrations, positioning for all types of examinations, darkroom technique, office routine, and operation of the mobile field unit. A number of radiologic technicians were also trained at Newton D. Baker General Hospital, Martinsburg, W. Va., Billings General Hospital, Indianapolis, Ind., Brooke General Hospital, San Antonio, Tex., Deshon General Hospital, Butler, Pa., Thomas M. England General Hospital, Atlantic City, N.J., Fletcher General Hospital, Cambridge, Ohio, Letterman General Hospital, San Francisco, Calif., Moore General Hospital, Swannanoa, N.C., and Nichols General Hospital, Louisville, Ky. These hospitals were especially suited for this work by reason of their facilities and staffs.

Hospitals varied in their teaching methods. At Fletcher General Hospital, each new student was assigned to an experienced technician, who taught him the practical aspects of his work. All students attended two lectures each week on the basic principles of X-ray physics and techniques. After 3 to 6 months, depending upon progress and aptitude, the student was given the responsibility, under supervision, for some of the departmental work. Since trained technicians were difficult to hold, it was the policy to have two or three men in training at all times; otherwise, the department might be suddenly depleted of skilled personnel and its efficiency greatly impaired.

Formal Medical Department schools for enlisted technicians were conducted at Fitzsimons General Hospital, Lawson General Hospital, O'Reilly General Hospital, and William Beaumont General Hospital, El Paso, Tex. The medical officers who staffed these schools and other courses for technicians rendered a most important and noteworthy service.[1]

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[1] Radiologists fully appreciated the work of these instructors, whether it was formal or informal. The officers who served under the editor of this volume, Dr. (then Colonel, MC) Kenneth D. A. Allen, still hold him in fond and affectionate regard. When they gather every year or two at a luncheon meeting in his honor, at the annual sessions of the Radiological Society of North America, they never fail to recall his ability to take farm boys and factory workers and, within a few weeks, turn them into competent technicians. The plaque honoring him for his work as Consultant in Radiology, European theater, was presented to him at one of these meetings (fig. 37).—A. B. S. and B. C.

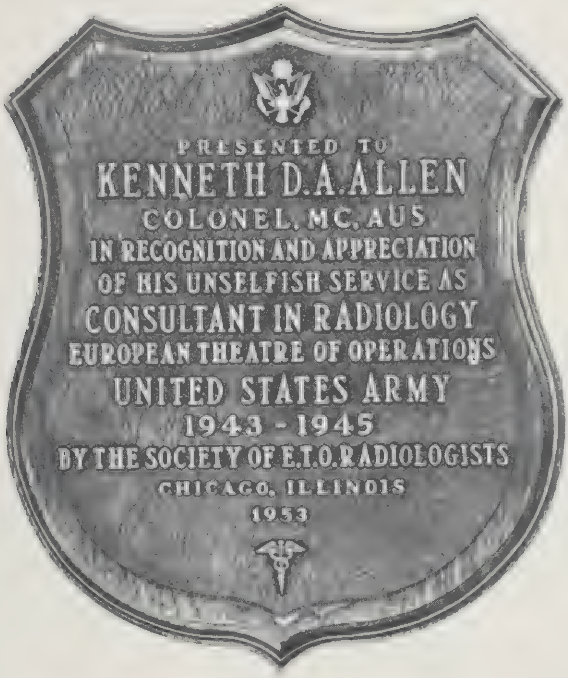

FIGURE 37.—Plaque presented to Col. Kenneth D. A. Allen, MC, in recognition of his services as Consultant in Radiology, European theater.

Although the technicians schools were organized and activated without much time for planning, they handled a phenomenally large number of students. The school at O'Reilly General Hospital, which was opened on 6 July 1942, had 367 students in its first group, 51 of whom were training as X-ray technicians. All but 2 of the 51 completed the course satisfactorily and were graduated with the first (complete) class of 341 technicians at the end of September 1942. The capacity of the school, originally set at 1,000, was shortly increased to 1,750, and the X-ray, dental, and laboratory sections were obliged to conduct day and night classes to carry the load.

In September 1944, the school at O'Reilly General Hospital received four women from nearby Drury and Northeast Missouri State Teachers Colleges to train as X-ray technicians.

Medical Department Technicians School

Lawson General Hospital

The technicians school at Lawson General Hospital (*2*) was activated on 1 July 1942, and the following data, from the annual report of the X-ray

section for the fiscal year ending on 30 June 1944, are indicative of its growth and activities:

On 1 July 1943, 12 months after activation of the school, teaching personnel had expanded from an initial strength of 20 officers and 35 enlisted men to 54 officers and 163 enlisted men. During the first year, 5,390 technicians had been graduated. The accelerated program in operation during this year required two shifts a day, the training day beginning at 0600 hours and ending at 2200 hours. Effective September 1943, the authorized allotment of trainees was reduced to 1,000 and the last night class was graduated in November 1943. In March 1944, however, the authorized allotment had to be raised to 2,000 and in April 1944, teaching in two shifts a day had to be resumed.

The teaching staff of the school was entirely separate from the Lawson General Hospital staff. During the accelerated courses given in the first year of operation, the radiologic instructional staff consisted of 6 medical officers and 12 enlisted men. During 1943–44, it consisted of three medical officers (one major and two captains), eight enlisted men, and one Wac.

Course of study.—The stated mission of the X-ray section of the school was to develop enlisted men with "an intelligent understanding of the operation and maintenance of X-ray equipment and an efficient degree of manipulative skill for all types of radiographic procedures so that they can properly function in fixed and mobile installations of the Medical Department." X-ray, dental, and laboratory technicians were also given enough instruction in emergency medical care, malaria control, and intravenous therapy for them to perform efficiently, in emergencies, as medical corpsmen.

The course at Lawson General Hospital, originally 3 months in length, was increased on 29 August 1943 to 4 months and was varied, as time passed, to meet the needs of individual students and the contingencies which arose overseas, as evident in comments received from theaters of operations. On one occasion, for instance, the Consultant in Radiology, Office of The Surgeon General, acting on such information, recommended that the technicians schools emphasize the importance of developing, fixing, and washing of films and the recognition of wornout solutions.

The first 4 weeks of the 3-month course were devoted to basic theoretical principles and to practical aspects of electricity and the production of X-rays, to the construction and use of X-ray units and the accessory equipment, and to various phases of darkroom construction and technique. Both routine and specialized procedures were covered, and much time was devoted to radiography of simulated casualties under field conditions. Clinical experience was provided by patients hospitalized in the school infirmary, as well as at local hospitals.

The increased time for the course authorized in August 1943 was devoted to practical work. Ten days were devoted to maintenance and repairs of all types of field equipment; 5 days to field duty, including foreign body localization, use of the biplane marker and orienting devices (p. 75), and packing, assembly, and use of field equipment; and 15 days to hospital training, which provided practical experience in the use of equipment and the handling of patients. The added time proved to be of great value, for the practical experience engendered self-confidence in the new technicians and enhanced their ability to handle both machines and patients.

During the fourth month, the students were divided into two groups, one for hospital practice and the other for the so-called troubleshooting course and field practice; the groups were interchanged at the middle of each month.

In the troubleshooting class, the approach was entirely through conferences and practical exercises, with great emphasis on the latter phase of instruction. A simplified, systematic procedure was carried out for the isolation of trouble in the field unit. Specific operating difficulties were created in the equipment, and each student was required to diagnose and isolate them and to correct them if possible.

Clinical experience, as already noted, was secured at the school infirmary, at Lawson

General Hospital, and at five hospitals in Atlanta, which cooperated in the program. School military personnel were also examined, and routine roentgenograms were made of 345 civilian hospital employees. For hospital practice, students were divided into small groups, never more than four, and were sent to the community hospitals, where they received individual attention and considerable practical experience, since all hospitals, being short of manpower, utilized the technicians to the fullest. The proximity of all the hospitals to the school permitted close supervision of the trainees by the school faculty.

As time passed, more and more emphasis was placed upon individualized instruction. A reduction in the number of trainees in 1943–44, as well as an increase in equipment, made this possible. Fine cooperation was received from all sections of Lawson General Hospital, particularly from the surgical section.

At the end of his tour of hospital duty, each student submitted a comprehensive report of the work he had performed. Examinations given at the end of each course were comprehensive and designed to test the student's knowledge of both theory and practice. Much time and thought were put into developing examinations which would instruct as well as test, and eventually, an extensive file of questions was created.

Equipment.—The school began with certain basic equipment and soon acquired whatever additional items were necessary. Some of it was secured by salvage from the station hospital at Fort McPherson, and some was donated by the General Electric X-Ray Corp. from a nearby civilian hospital. In 1944, new and improved visual aid material was secured, including models; boards illustrating machine circuits; demonstration material for foreign body localization with the field unit; and other diagrams, charts, and slides. Appropriate films produced by the Signal Corps and by commercial film libraries were also used.

A classroom in a building near the main X-ray section was converted to a demonstration workshop for the maintenance phase of the course, and grounds near the section were utilized for field classes.

Statistical data.—Of the 255 students enrolled in the Medical Department Technicians School at Lawson General Hospital for X-ray training in 1943–44, 116 came from replacement training centers; 117 from the Fourth Service Command; 5 each from the Army Ground Forces and the Army Service Forces Unit Training Command; 11 from the Office of the Chief of Transportation; and 1 each from the Eastern Defense Command and First U.S. Army. In general, students from the replacement training centers presented the best educational background. Students from other sources often did not have the correct requirements, though an improvement was noted after 5 April 1944, when the Office of The Surgeon General directed specific compliance with all specified educational requirements. It is only fair to add that a number of students without the proper educational background were able, by hard work and intensive desire, to pass the course and become excellent technicians.

Of the 341 students graduated as X-ray technicians during fiscal 1944, 31 had college degrees and 10 had less than 2 years of high school. Of the remainder, 97 had attended college from 1 to 4 years, 168 were high school graduates, and 35 had attended high school for 2 years or more. The extent of their previous education and their Army Classification Test Scores were generally reflected in the final ratings the students received. Thus, 27 of the 31 college graduates had excellent or superior ratings, but only 1 of the 10 students with less than 2 years of high school was in the group.

Between 1 July 1943 and 30 June 1944, the students at the school at Lawson General Hospital were able to examine 2,075 individual patients at the school infirmary in 2,294 separate studies. Of these, 1,581 examinations were of the chest, and 374 of the extremities. The more complicated examinations, such as gastrointestinal studies, barium enemas, bronchograms, and cholecystograms, were usually made at Lawson General Hospital.

During 1943–44, the admissions in the X-ray section of the school varied from 59 in

May 1944 to none in April and in June of that year. It would have been desirable, in order to make the best use of teaching personnel and equipment, to keep the admissions fairly constant, at an average of about 20 per month, but it was realized that this was probably not possible.

CONFERENCES

One of the important functions of an X-ray department was to present radiographs of their patients to medical officers and discuss the findings with them. It was equally important to devise some sort of system by which this function could be carried out without the duplications of showing the same films to different officers several times a day, as well as without constant interruption of the work of the department. No hospital ever solved the problem completely, but departmental efficiency was increased when serious efforts were made to solve it, chiefly by the use of conferences, which were variously employed:

1. Some X-ray departments scheduled daily conferences, at specified hours, for reviewing the films taken the previous day, both for their own personnel and for representatives of the medical and surgical sections.

2. Some departments scheduled weekly conferences, or conferences several times a week, with the staffs of other sections. At Halloran and Nichols General Hospitals, for instance, conferences were held daily at 0800 hours with the surgical and orthopedic staffs and once weekly with the medical staff. At Newton D. Baker and Fletcher General Hospitals, where conferences were held twice weekly, all the films made since the last conference were demonstrated and discussed in connection with the clinical history in each case. All of these hospitals found that one indirect result of this policy was a considerable reduction in indiscriminate requests for radiographs, presumably because the officers who were requesting them were impressed by the large number of negative films shown at each conference.

3. No matter what the departmental policy was concerning them, these conferences were always an integral part of the teaching and training program. At Percy Jones General Hospital, Battle Creek, Mich., they were designed for this purpose. Conferences were held once a week for the medical and surgical services, with all members of the X-ray section present, including such technicians as could be spared. Another conference, held every Saturday from 1300 to 1400 hours, served as a forum to acquaint members of the staff of all departments with the most interesting and challenging cases encountered. When the films were interpreted daily in the department, the interesting cases were listed, and in the middle of the week, about six, representing all services, were selected for presentation the following Saturday. The ward officers presented the findings in their own cases, after which a general discussion ensued, guided by members of the X-ray staff so that younger men on the various services would be encouraged to ask questions and otherwise participate. The greatest interest was always expressed in the cases in which the diagnosis had not been established at the time they were originally presented and which were brought up again at later conferences,

after the diagnosis had been made. The time spent on each case depended upon the interest of the conferees in it, but it was only occasionally that all six cases listed for each meeting were discussed.

At Bushnell General Hospital, where medical students from Vanderbilt University School of Medicine received part of their training, weekly X-ray conferences were held for them during their 6 weeks of intership and were also attended by a number of staff officers and technicians.

FACILITIES

Named general hospitals in the Zone of Interior had three types of X-ray facilities, depending upon the structure of the hospitals in which the sections were located:

1. The multistory permanent structures, such as Letterman, Fitzsimons, Brooke, and Walter Reed General Hospitals, which had been in operation long before World War II.

2. Converted buildings originally intended for civilian hospitals and sanatoriums or for schools and hotels. In this category were such named general hospitals as Ream, which occupied The Breakers, Palm Beach, Fla.; Thomas M. England, which occupied Chalfonte-Hadden Hall, the Traymore, and several other hotels in Atlantic City, N.J.; Ashford, which occupied the Greenbrier, White Sulphur Springs, W. Va.; Torney, which occupied El Mirador, Palm Springs, Calif.; and Gardiner, which occupied the Chicago Beach Hotel, Chicago, Ill. As a rule, hotels could be readily adapted to hospital use, and they were highly desirable from the point of view of the X-ray department because their elevators permitted the transfer of patients from and to wards with reasonable speed.

3. Cantonment hospitals, of wood, brick, stucco, or tile, built expressly for the war emergency, such as Thayer and Battey General Hospitals, Cushing General Hospital, Framingham, Mass., Dibble General Hospital, Menlo Park, Calif., Finney General Hospital, Thomasville, Ga., and Lawson General Hospital.

X-ray facilities in the large military hospitals in existence before the war were generally well planned, though the increased workload often required that they be expanded. In many converted hospitals, and in some of the newly built hospitals, the facilities often left much to be desired. It was not always practical to consult the radiologist to be assigned to the hospital before radiologic facilities were allotted and constructed, but it was an unwise and expensive error not to seek such consultation in advance whenever it was possible.[2]

The changes necessary in facilities set up without radiologic consultation are well illustrated by the situation at DeWitt General Hospital. When Capt.

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[2] Not very helpful was the query received by one radiologist, while awaiting orders to proceed to his permanent assignment, from his future commanding officer, asking if he would indicate on the plans of the hospital where he wanted his "shadow box" located, so that an electric outlet could be installed for it.

(later Lt. Col.) Walter E. Scribner, MC, saw the plans for the X-ray department, he protested but was told that matters of construction were not his affair. When the building was completed, the facilities were found inadequate in every respect. The space allotted for control booths was too small. Radiators were placed directly in front of the exit from each of these booths into the diagnostic room which the booth serviced. No space had been provided in the office for viewing boxes. The area intended for film storage had obviously been planned in ignorance that safety X-ray film was presently available. The room, 12 by 14 feet, had thick concrete walls, a concrete ceiling, a heavy concrete floor, a metal-covered door, and a ceiling fan. There were no shelves, and no other facilities had been provided for storing film.

When the chief of the orthopedic section saw the room designated for orthopedic radiology (it had one sink and no electric outlets), he flatly refused to use it.

There was only one tank in the darkroom, with two inserts, one for 10 gallons and one for 15 gallons. The only washing space available was between the tanks, and the 36-inch wash tank finally inserted into it was not satisfactory because there was no outflow arrangement and the water could not be kept flowing freely.

A major reconstruction job had to be carried out in this department, at great expenditure of time and money. When it was found that, even after the radiators in front of the doors of the control booths were removed, the space was still too small to contain the controls, the walls were torn out and the whole space was reconstructed into three diagnostic rooms, a small room for superficial therapy, an office, and darkroom space. The rejected orthopedic room was converted into a secretary's office and space for filing films.

The orthopedic radiologic section was moved to another barracks-type building, where a cast room was created, equipped with a Picker portable unit. Part of the solarium was converted into a fully equipped darkroom. Two X-ray technicians were detailed to this section, and all orthopedic radiologic work (from 700 to 800 examinations per month, 50 to 60 checks daily) was done in it. The orthopedic surgeons saw the wet films in their own darkroom, determined whether the results were satisfactory, and proceeded to the next case with no loss of time. All radiographs made in this separate facility were held for the weekly orthopedic-radiologic conference.

At Fletcher General Hospital, many structural changes were necessary to provide adequate X-ray facilities, and additional wiring was required for both the machines and the auxiliary lighting. Since neither the fluoroscopic room nor the darkrooms were adequately lightproofed, all shades and window casings in both rooms had to be changed and lightproof shutters installed. Light leaks in the walls and ceilings of these rooms were difficult to control because of settling of the building and shrinkage of the building material. They were finally overcome by the use of caulking compound and quarter round at all angles and joints, and by painting the rooms dark green, to avoid

reflected light. Cabinets for supplies and shelves for filing films had not been provided and had to be built.

At Torney General Hospital, a number of basic changes were necessary. Another control booth was required. The orthopedic room was much too small. The darkroom had to be remodeled and rearranged, so that film driers could be moved into it from the hallway. The maze and the dressing room of one fluoroscopic room were removed and incorporated in the darkroom, and a more lightproof entrance was provided by an anteroom and a two-door arrangement, with electrical locks. The floor was covered with asphalt tile. A lightproof pass box was installed. Air conditioning was installed in the three fluoroscopic rooms and the darkroom, and dampers were placed on the exhaust mechanisms of the driers to remove air from the darkroom.

In contrast to the situation at the hospitals mentioned, as well as at many other hospitals, was the situation at Lawson General Hospital. Here, the advice of the radiologist, Maj. (later Lt. Col.) John L. Barner, MC, was requested before the hospital was completed, and authority was obtained from the War Department to alter the plans to meet his suggestions. The basic result was satisfactory in every respect, though many additions were later necessary, including a supplementary darkroom, as the workload increased (from 22,000 examinations in 1942 to over 30,000 in 1943).

There were two general complaints about X-ray facilities. One was the waiting space, which was frequently totally inadequate and sometimes had not been provided for at all. Colonel Kirklin, as well as the surgical consultants who inspected the X-ray departments in the service commands, repeatedly commented on this lack, which at times required as many as 50 to 60 patients to sprawl out on the hall floor.

The second complaint was the distance of the X-ray service from other departments, chiefly orthopedic surgery and urology, which in many ways needed it most. Whenever possible, this difficulty was solved, as already indicated, by the construction of separate facilities for the orthopedic section and sometimes for urology. At Kennedy General Hospital, separate X-ray facilities were set up for medicine and for surgery, chiefly urologic surgery. Later, separate facilities were also set up for the orthopedic section.

At varying times during the war, air conditioning was installed in a number of X-ray departments.

Protection.—Protection of personnel was generally adequate in named general hospitals in the Zone of Interior. It was better, of course, in some hospitals than in others. At Schick General Hospital, a newly built, semipermanent brick structure, all the machine rooms in the department had leadlined walls and leadlined control booths, which gave adequate protection against stray radiation. The use of aprons and gloves was mandatory at all installations.

The chief potential hazard occurred during fluoroscopy, when the cassette had to be held against the fluoroscopic screen during spot-film radiography.

The field was made as small as possible by the use of lead shutters. Dental films placed inside the fingers of gloves showed no exposure, but it was realized that as the patient load increased, so would the risk. An attachment to the fluoroscopic screen to hold the cassette was not provided with the equipment then in use, but a number of hospitals developed their own spot-film devices that worked reasonably well and that minimized the radiation hazard to the operator.

EQUIPMENT

Heavy-Duty Equipment

The basic equipment of all X-ray departments in named general hospitals was the heavy-duty combined radiographic-fluoroscopic unit. When the United States entered the war, some hospitals were equipped with Philips Metalix machines, of Dutch manufacture. Since replacement parts were in short supply, all these machines were replaced as rapidly as possible with machines of domestic manufacture. The domestic machines were of rugged design, withstood hard usage, were seldom out of order, and were easy to operate. Technicians with only brief training were able to produce uniformly good radiographs with them.

At least two of these stationary units were provided for the X-ray department of each named general hospital. Some departments had three machines originally, and many acquired additional units during the course of the war. Some hospitals had five or more. When the load was heavy, three machines were not sufficient; Wakeman General Hospital, Camp Atterbury, Ind., had three machines, but the workload was so heavy that at intervals work had to be suspended for half an hour or more, to permit them to cool off.

Some of the equipment in use at the beginning of U.S. participation in the war, particularly in some of the older hospitals, was obsolete and non-shockproof. Equipment of this kind could be dangerous, as an incident at Walter Reed General Hospital illustrated: A mother was helping to place her 8-year-old son on the table when a concealed metal stiffener in the feather of her hat either came into contact with, or came near to, a bare wire of the machine. When Captain Wyatt arrived, in response to a frantic call from the technician, the mother was in one corner of the room, and the boy, who had swallowed his tongue and was turning blue, was in another. He was quickly restored to normal status by pulling his tongue out of his throat. The speed with which this machine and the other obsolete equipment at the hospital were then replaced probably set an Army record.

Most hospitals were adequately equipped when their X-ray departments were activated, but in a few instances, this was not true. Torney General Hospital, in 1942, had no equipment, and its first patients had to be sent to Camp Haan, in Los Angeles, for X-ray examination. The first equipment to arrive consisted of three portable field units, without fluoroscopic attachments, so it was still impossible to carry out gastrointestinal studies or fluoro-

scopic chest examinations. At this time, the hospital required about 1,100 radiographic examinations a month.

Mason General Hospital, when it was activated, had the basic heavy-duty machine, but the equipment was incomplete, and from July to September 1943, patients had to be transported to Camp Upton two or three times a week for X-ray examinations. In September 1943, several rooms were equipped for temporary use, and the X-ray service was supplied with a 30-ma. Picker field unit.

In contrast to these early deficiencies, some X-ray departments were adequately equipped from the beginning. Ashford General Hospital, for instance, had two single-tube fluoroscopic-radiographic heavy-duty machines, later replaced by two-tube 200-ma. machines, two 30-ma. bedside units, one Army field unit with table, one 150-ma. urologic unit, and one 30-ma. machine inherited from the Greenbrier Hotel medical equipment.

Percy Jones General Hospital had a centrally located, well planned, completely equipped X-ray department covering 6,000 square feet, with all the necessary basic equipment, including tilt tables, quick changeover switches, and spot-film tunnels for compression exposures for gastrointestinal and myelographic studies. There were two cystoscopic tables in the urologic section, with a single transformer and high-tension switch, which permitted the use of either table. The department had a separate orthopedic X-ray section. It also had one of the first Morgan-Hodges phototimers to be put into use (p. 162), which was personally installed by Dr. Paul C. Hodges of Billings Memorial Hospital, Chicago, Ill.

At Thayer General Hospital, a Westinghouse head Bucky with attached tube was installed in one of the radiographic rooms; this sturdy and useful accessory permitted sinus examinations in the upright position, encephalography, and difficult examinations of extremities.

Specialty centers were provided with special equipment to meet their individual requirements. Such equipment was particularly needed in neurosurgical and orthopedic centers. Mason General Hospital, which was a neuropsychiatric center, needed a machine which permitted rapid exposures, but the 500-ma. machine asked for was not procurable.

Tubes.—Eventually, all X-ray departments in general hospitals in the Zone of Interior were equipped with rotating anode tubes, but this did not happen at once. Originally, requisitions for these tubes, even when recommended by the Consultant in Radiology, were not, or could not be, honored by the Supply Division. The original stationary anode tubes held up quite well; at Schick General Hospital, for instance, one tube was used for 7,066 exposures before it punctured. Rotating tubes, however, were far better. At DeWitt General Hospital, the tube installed in April 1945 had been used for 15,090 exposures by the end of December, with no trouble at all. The life of these tubes was so long and the quality of work done with them was so fine that it was generally believed that their original installation in all busy X-ray

departments would have yielded savings in retakes and tube replacements that would have more than compensated for their original higher cost.

It was unfortunate that tables of equipment did not provide for spare valve tubes and spare X-ray tubes. When these essential components of the unit wore out or became defective, the machine was useless until the replacement arrived, which was sometimes a matter of weeks. No tubes were stocked on the west coast, and when one burned out at DeWitt General Hospital, it had to be shipped from the East and did not arrive for 6 weeks.

Portable Equipment

The Picker portable field unit (p. 925), although designed primarily for field use overseas, served admirably in Zone of Interior hospitals for bedside radiography. It was too heavy and unwieldy to be rolled for long distances, especially if steep grades were encountered, but its simplicity of construction and operation and the overall fine engineering that went into it produced a machine which gave long service without breakdowns. Technicians who had used it overseas declared that no tube in a field unit had ever burned out, and equally enthusiastic paratroopers declared that this unit could be dropped by parachute and be in operation within a matter of minutes.

Large hospitals, such as Fitzsimons General Hospital, had as many as 15 field units. When machines were available in such numbers, they were installed in the orthopedic and urologic clinics and wards and also spotted around the hospital, to avoid long hauls to the patient's bedside.

The attachment for the localization of foreign bodies, into which so much effort had gone (p. 72), was as infrequently used in the United States as it was overseas.

Current

The difficulties with current that plagued so many hospitals overseas were seldom experienced in the United States. At Thayer General Hospital, however, in 1943, the 220-volt separate incoming line provided about 250 volts, and a stepdown transformer had to be installed. Radiologic technique suffered considerably before the installation was completed. At Newton D. Baker General Hospital, line fluctuations and variations in milliamperage affected the quality of the films, and though the situation was greatly improved, the cause of the difficulty was never discovered.

Accessory Equipment

It is not always easy to draw the line between essential accessory X-ray equipment and devices that are useful, save time, and improve film quality but that are not absolutely necessary to radiologic performance. The intercommunications systems finally installed in some X-ray departments increased

efficiency and were a great convenience, but they were in the class of luxuries. The department at O'Reilly General Hospital had a human skeleton and an electric typewriter as well as all of the accessory equipment it needed except for an adequate drier.

Eventually, all the necessary accessory equipment was on hand in all installations, but some hospitals were greatly handicapped by initial deficiencies. Bushnell General Hospital, for instance, had all basic X-ray equipment in place when it was activated in October 1942, but much of the accessory equipment was not on hand, including cassettes, films, and darkroom supplies. Repeated appeals through official channels produced no results, but when local radiologists learned of the difficulties, they promptly produced enough materials for the department to operate until its own supplies arrived. Other hospitals were also able to borrow what was needed or to improvise it.

At Fletcher General Hospital, requisitions for a number of accessory items which the department considered necessary for good radiologic work were disapproved, including the spot-film device essential for effective gastrointestinal studies. The post engineers, working from plans drawn by the radiology department, built a device, at a cost of $3, which proved almost as satisfactory as the commercial device, which cost $400. At McCaw General Hospital, Walla Walla, Wash., Maj. (later Lt. Col.) Gerhard Danelius, MC, constructed an inexpensive laminograph that produced radiographs comparable in quality to those produced by the expensive commercial equipment. In a number of other hospitals, radiologists and technicians built their own spot-film devices out of materials at hand.

At Mason General Hospital in 1943, when basic equipment was incomplete and the U.S. field unit had to be used for heavy duty, an X-ray table was improvised by using two wooden kitchen tables with a Bucky diaphragm between them at the level of their tops. A cassette holder, darkroom equipment, and other necessary items were also improvised.

At Fletcher General Hospital, the film-processing tanks proved far too small for the volume of work . The post engineers built and installed a master tank, and 20-gallon inserts were built, without charge, by the Reynolds Moulded Plastic Co. The film-developing capacity of the darkroom was thus doubled. An aerator was devised by Major Scribner at DeWitt General Hospital (*3*). At O'Reilly General Hospital, where facilities for drying films were inadequate, a device was fabricated with a total capacity of 54 films.

When cassettes were in short supply, cardboard film holders were used. When lead markers were provided in insufficient numbers, several hospitals made plaster molds, melted sheet lead, and made their own markers.

In short, most deficiencies were eventually overcome by the arrival of the necessary items, and until then, the ingenuity of radiologists and technicians, combined with the assistance of local radiologists, closed the gap.

Maintenance problems were materially reduced when all X-ray equipment provided for a department was of the same manufacture. Very often it was not. At Newton D. Baker General Hospital, the original equipment

consisted of two Keleket 200-ma. combination radiographic-fluoroscopic stationary units, one Philips Metalix energizing unit for the cystoscopic table, one 2-position Continental fluoroscopic unit, two 30-ma. Picker Army field units, and one 30-ma. Keleket bedside unit. In April 1945, the Continental unit was moved to the cardiac ward and was replaced by a 200-ma. Mattern combination fluoroscopic-radiographic unit.

An efficient maintenance service was eventually set up in the Zone of Interior, but its existence was at first not so well publicized as it should have been, as the Consultant in Radiology pointed out on one of his tours of inspection. When the service was fully established, the medical equipment maintenance officer at each supply depot visited the various stations in the command, checked equipment, and advised on its maintenance. He also cared for emergency repairs. There was universal testimony to his helpfulness.

The need for repairs of X-ray equipment was surprisingly infrequent because of the excellent quality and performance capacity of the machines in use. At many hospitals, technicians were able to take care of both maintenance and repairs. At several hospitals, the personnel included men who had worked as servicemen for X-ray companies in civilian life, and they, sometimes with the help of post engineers, were usually able to care for all but major repairs.

Critique

The performance of the equipment provided in World War II was, as just indicated, excellent. The chief criticisms concerned delay in receiving all the items necessary when departments began to operate and delay in receiving part replacements, particularly X-ray tubes.

Recommendations for X-ray equipment in the event of future hostilities included the provision of generators of at least 200-ma. capacity; heavy-duty rotating anode tubes; sturdy spot-film devices; simplified controls; simplified tilt tables; and automatic film processors. In the light of the World War II experience, it was considered imperative that at least one X-ray tube be kept on hand in each hospital for emergencies and that, if valve tube rectification was used, at least two extra valve tubes should also be kept on hand.

One radiologist, asked to list equipment he would consider essential in a future war, wrote as follows:

> In the light of our experience, without philosophizing about the extent and nature of casualties in future wars, I would suggest four diagnostic rooms for a hospital of about 1,500 beds, two of these rooms to contain fluoroscopic-radiographic units, with phototiming in the fluoroscope only. The other units might be radiographic only, but all with tilt tables, so that the Bucky diaphragms might be used erect. I would also include a superficial therapy room. Two small automatic processors (instead of one larger unit) in the main darkroom. If a separate orthopedic installation is to be made elsewhere in the hospital, it too should have its own automatic processor. In larger installations, image amplification might be desirable. Neurosurgical centers would need special head units. One or two machines with special tables should be provided in each GU installation.

A goodly number of mobile units, such as the old Picker, should also be standard items.

Basic accessory equipment might include a laminographic apparatus, Polaroid cassettes and processing machine, the simplest eyelocalizer obtainable, probably the Sweet, a number of the Smith-type immobilizing gadgets, as well as the usual cassettes. There should always be a regular tank setup in the darkroom as a standby for the automatic processors.

FILMS

Films were usually in adequate supply and were usually used with economy, though the range was considerable, varying from an average of 1.34 films in 2,223 examinations at Thayer General Hospital to 2.6 in 1,473 examinations at Foster General Hospital, Jackson, Miss., somewhat higher than the average. An average of 1.53 films per examination was regarded as conservative.

At many hospitals, it was the practice to make multiple exposures on single films, particularly in X-raying the sinuses and other small parts of the body and in polygraphic work. At William Beaumont General Hospital, films which arrived with patients were always carefully examined before others were ordered; often, additional examinations proved entirely unnecessary. Attention has been called elsewhere (p. 144) to the reduction in requests produced by the demonstration of large numbers of negative films. Instruction and supervision of technicians kept waste from technical errors low.

Films were generally received in good condition, but occasionally, as in oversea theaters, fogging was noted. Investigation revealed several causes, including outdating and solder material in the developing tank, as had been observed in the European theater (p. 394).

Current, as already mentioned (p. 136), seldom furnished difficulties in U.S. general hospitals, but occasionally, fluctuations were found responsible for fogging of films. At Gardiner General Hospital, where the orthopedic consultant for the Sixth Service Command criticized the films as to quality and detail, Colonel Kirklin found two causes for the trouble: The first was the performance of the Philips Metalix machine (p. 784); the second was overloaded current supply. Large numbers of radiographs were being made on portable machines plugged in the house current, which was highly variable; on dark days, when many lights were burning, as well as at night, less current was available for X-ray use and results could not be standardized. When the equipment was changed and the supply of current was standardized, the quality of the films at this hospital immediately improved.

At Walter Reed General Hospital, variations in film density were frequent. Captain Wyatt, who was appointed to investigate the trouble, found that density varied from machine to machine, as well as at different times on the same machine, and was too great to be tolerated. The fault was traced to the developing time. At this time, a time-temperature development technique was in use, and the films were being underdeveloped, so that any variation at all in exposure was intensified in the darkroom. The trouble was

readily corrected by carrying the developing time 1 minute beyond the time thought to be necessary for complete film development. From this experience came the concept, later generally adopted, that there is no such thing as overdevelopment of an X-ray film. A film can be incompletely developed or chemically fogged, but it cannot be overdeveloped because no amount of development can bring out of it anything more than has been put onto it by the exposure.

The automatic processing chain system later put into use at Walter Reed General Hospital was one of the first in the country. It was planned by Colonel Hampton and Sergeant Miller, and it proved most efficient.

Preservation and storage.—The chief of the radiology service was responsible for the safekeeping of films, and his task was not simple. Consultations in the X-ray department were encouraged (p. 130) as the simplest method of keeping films safe, but they were not always practical. When the films were released to the wards, they were often lost or misplaced—when a film was placed in the wrong envelope, it was lost for all practical purposes. Before the war ended, a good many departments had adopted the practice of loaning films for use on the wards only on written request, with their delivery signed for, and with a specified time limit for the loan. At Thayer General Hospital, in 1944, the plan was adopted of keeping the original film and the last two films on the wards. The method required a good deal of clerical work, but it kept the loss of films down.

Attention has been called elsewhere to the frequent lack of storage space for films (p. 132). When thousands of films were being made every year, the amount of space required for this purpose was very large.

RADIATION THERAPY

Radiation therapy in named general hospitals in the Zone of Interior is described, with particular reference to the supervoltage therapy available only at Walter Reed General Hospital, in a separate chapter in this volume (p. 198). Not much else needs be said about it.

A number of general hospitals were authorized to provide deep therapy but the apparatus for it, although authorized, was not provided unless justification for its issue could be advanced. Several applications were refused.

Superficial X-ray therapy was applied in a number of hospitals but its indiscriminate use was also discouraged, especially in dermatologic conditions. The use of the Army field unit for this purpose was finally restricted to installations in which the radiologist was qualified in therapeutic radiology. Deep therapy was administered at a number of centers. Unusually excellent work was done at Lawson General Hospital, of which the chief of section, Major Barner, had had superior training, part of it at Memorial Hospital in New York.

Radium was provided only at Letterman General Hospital, Walter Reed General Hospital, and Army and Navy General Hospital, Hot Springs, Ark.

The restrictions on radiation therapy usually worked no hardship, but a special situation arose in the spring of 1945, when Dr. Robert G. Ivy and Dr. Jerome P. Webster, Civilian Consultants in Plastic Surgery to The Surgeon General, visited the plastic surgery center at Wakeman General Hospital. Here, they observed many hypertrophied scars, which they thought would be benefited by the application of X-rays either before or after operation. They were told, however, that no radiation therapy was permitted in the hospital and that the patients would have to be transferred for it to some hospital with a qualified radiotherapist on its staff. This plan was considered impractical by the consultants because the routine of management, which required plastic surgery within a few days of radiation therapy, would be disrupted by it. The consultants pointed out that the application required was extremely superficial, that the only equipment necessary for it was that supplied for diagnostic purposes, and that the machine could be readily calibrated and the dosage thoroughly controlled. They recommended that, in similar situations, radiologists qualified in diagnostic therapy be permitted to administer the treatment required or that a trained radiotherapist be added to the staff of each plastic center. The war ended before action was taken on these recommendations.

At Fitzsimons General Hospital, during 1942, there were 1,747 applications of superficial X-ray therapy and 1,214 applications of deep X-ray therapy. For 1943, the respective figures were 3,623 and 2,918; for 1944, 957 and 2,626; and for 1945, 2,995 and 4,050.

Statistical data for 1945 at DeWitt General Hospital for superficial X-ray therapy may be cited as generally typical of the use of this modality in named general hospitals in the Zone of Interior. During this year, there were 794 consultations for X-ray therapy; 2,132 patient visits to the section, including 831 outpatient visits; and 9,839 fields treated. The 704 patients treated as new cases during the year presented the following conditions:

Pathologic state	*Number of cases*	*Pathologic state*	*Number of cases*
Acne (all types)	100	Furuncle	12
Adenitis (nonspecific)	1	Hyperhidrosis	20
Bursitis	1	Keloid	12
Cellulitis	2	Lichen planus	17
Dermatitis, eczematoid	128	Lymphangioma	1
Dermatitis, exfoliative	2	Neurodermatitis	28
Dermatitis, pustular	3	Onychomycosis	20
Dermatitis, lichenoid	46	Paronychia	1
Eczema, follicular	10	Pruritus ani	8
Eczema, seborrheic	21	Sycosis barbae	25
Eczema, chronic	30	Trichophytosis	167
Eczema, nummular	5	Verrucae (plantar)	44

PHOTOGRAPHY

Several named general hospitals in the Zone of Interior developed sections of photography as part of their X-ray sections or departments. Usually,

the effort began on an amateur basis, in response to needs and requests, and then became fully functional.

The photographic section at Schick General Hospital, which eventually became an active and highly developed appendage to the radiologic service, developed in this way. In 1943, photographic activities were housed in inadequate space in a small storage closet and were carried out by a radiologic officer in his spare time between other duties or in his off-duty time. With increasing demands for prints of radiographs and slides for lectures, the need for larger quarters and regularly assigned personnel became evident. Therefore, when the X-ray section was enlarged and its arrangements altered, the photography section was given a room 7 by 10 feet, and an enlisted man, well qualified in photography, was put in charge. The improvement was immediate. The prints were of finer quality, and production kept up with greatly increased demands for the service, though supplies and equipment were still procured with some difficulty. In 1944, Schick General Hospital was designated as a photographic center. During the year, production amounted to 4,300 photographs; 3,800 prints; 1,200 lantern slides, chiefly for teaching purposes; 325 Kodachrome slides; 1,200 feet of motion pictures; and 800 feet of 16-mm. Kodachrome motion pictures. In all, 10,687 separate procedures were completed.

Captain Wyatt, at Walter Reed General Hospital, also developed a photographic service in connection with the radiologic service. With Capt. (later Maj.) William Spears Randall, Jr., MC, of the Pathology Section, he made a study of benign and malignant bone lesions, in which the radiologic and histologic aspects were correlated. The study was the basis of an instructional course given for several years at the American Roentgen Ray Society; it is now in the files of the Armed Forces Institute of Pathology.

At the 1944 joint meeting of the American Roentgen Ray Society and the Radiological Society of North America, Major Barner and his associates at Lawson General Hospital presented an exhibit of bone lesions. It covered 76 cases and consisted of 112 radiographs and other illustrations, as well as summarized histories, pertinent laboratory studies, and final pathologic reports.

CIRCULATING FILM LIBRARY

At the suggestion of radiologists at Halloran General Hospital, a traveling collection of radiographs of interesting and unusual cases was developed, made up of material solicited from every X-ray section in the Second Service Command (*4*). The total collection consisted of about 50 individual presentations, assembled in 3 looseleaf binders, each of which held about seventy-five 14- by 17-inch films. Each presentation consisted of a typed summary of the case and the illustrative films for it.

The subjects covered included a wide variety of combat injuries; lesions of cervical disks, demonstrated by myelography with Pantopaque (ethyl iodophenylundecylate); bone and joint lesions in paraplegics; venograms of

the upper and lower extremities; virus pneumonias; intraocular foreign bodies, with techniques of localization; sarcoidosis; and leprosy, the material for which was contributed by Col. (later Maj. Gen.) James P. Cooney, MC.

The collection was sent in rotation to the chief of the X-ray service in each general and each station hospital in the command, to be kept for a maximum of 4 days before it was sent to the next installation. When the collection was circulated for the second time, each X-ray department removed its original contribution and replaced it with a new one.

The preparation of this film library was an interesting and profitable experience for all the medical officers who worked on it. The collection was of significant teaching value and was so used in many of the hospitals to which it circulated. It was particularly appreciated by younger medical officers, with limited experience in radiology before they entered the Army.

LIAISON

Liaison on the part of radiologic sections of named general hospitals in the Zone of Interior had three aspects:

1. Liaison between the radiologic section and other sections of the hospital. It was exceptional for a warm and cordial relation not to exist, the most obvious expression of it being the joint conferences described elsewhere (p. 130). At Valley Forge General Hospital, Phoenixville, Pa., a sort of rotating arrangement was worked out, by which medical officers from other services were assigned to the radiologic section for periods of 2 to 4 weeks, to improve the departmental associations and promote better utilization of radiologic facilities.

2. Liaison between the radiologists of the named general hospitals and those of other hospitals in the vicinity. At Thayer General Hospital, for instance, Major Ivie, and Maj. (later Lt. Col.) Archie Fine, MC, chief of the radiologic service at the Army Air Forces Convalescent Hospital nearby, consulted each other on diagnostic problems, exchanged clinical experiences, and on several occasions supplemented each other's supplies until shortages of particular items could be made up.

3. Liaison between the radiologists of named general hospitals and those on the staffs of local medical schools and civilian hospitals or in private practice in the community. When general hospitals were located near teaching centers, the liaison was particularly profitable. Halloran General Hospital, for instance, located in the Borough of Richmond, was within 60 to 90 minutes of the several medical schools in Manhattan, and radiologists on the staff were able to attend teaching conferences and participate in special courses, such as those in neuroanatomy and neuropathology given at the College of Physicians and Surgeons, Columbia University, New York, N.Y. Conversely, students at the Vanderbilt University School of Medicine received part of their training at Thayer General Hospital.

The commanding officer of Hoff General Hospital, Santa Barbara, Calif., after learning from creditable sources that there was a true need for radiologic consultation in the community, permitted Maj. (later Lt. Col.) Arthur J. Present, MC, Chief of the Section of Radiology, to assist a local radiologist during his off-duty time. At Bushnell General Hospital, relations between hospital and community were particularly good because medical care was given to a large number of patients whose homes were nearby.

Finally, experienced civilian radiologists gave freely of their help whenever it was needed in military hospitals, including, as already mentioned, the loan of their own equipment when the need arose.

STATISTICAL DATA

The tendency to request unnecessary X-rays must be taken into consideration in evaluating the statistics of X-ray sections early in U.S. participation in the war. Later, chiefs of services exercised more control in this matter, one reason being Circular Letter No. 193, from the Office of The Surgeon General, dealing with elimination of unnecessary laboratory work (*5*). X-ray examinations were being made, the letter pointed out, "routinely, without due consideration of necessity." Films should not be made, it continued, "when there is no clinical reason to suspect disease in the part x-rayed." Chiefs of services were directed to "insist on individual consideration of cases in determining the need for laboratory examinations, to the end that unnecessary work be eliminated." In the absence of this directive, there is no doubt that the radiologic caseload would have been considerably heavier than it was.

The activity of the radiologic section naturally varied with the special mission of the hospital in which it was located. The heaviest workload, day in and day out, was probably carried by the hospitals which served as centers for orthopedic surgery, but even smaller hospitals were very active. Darnall General Hospital, which began as a 250-bed hospital and was later expanded to 921 beds, was a special center only for neuropsychiatry, but its radiologic service processed 3,841 films in 1943 and 8,544 in 1944.

A comprehensive statistical review of the work of X-ray sections in named general hospitals is not possible because, as noted elsewhere, annual reports were not required, and when they were submitted, they were not uniform. In fact, the statistical basis often varied in the same hospital from year to year, making comparative analyses impossible. In general, the use of X-rays tended steadily upward throughout the war, as the following statistics, selected at random, show:

Ashburn General Hospital, McKinney, Tex., reported 10,000 examinations in 1943, 11,862 in 1944, and 24,625 in 1945.

Halloran General Hospital reported 17,204 examinations in 1943, 19,484 in 1944, and 32,754 in 1945.

Torney General Hospital examined 10,189 patients and processed 27,503 films during 1944. During 1945, the respective figures were 16,895 and 29,057.

Lawson General Hospital examined 33,295 patients and processed 6,543 films in 1941. In 1942, it examined 21,475 patients, made 1,538 fluoroscopic examinations, and processed 38,635 films. In 1943, it examined 26,367 patients, made 1,523 fluoroscopic examinations, and processed 4,282 dozen films.

Oliver General Hospital, Augusta, Ga., made 32,555 X-ray examinations in 1945, one reason for the large number being that it served as a separation center during part of the year.

The breakdown of examinations for Stark General Hospital, Charleston, S.C., for 1943, which follows, corresponds, in general, to the data supplied by other hospitals. This hospital served as a special center for general and orthopedic surgery.

Area examined:	*Number of patients*	*Number of examinations*
Head	353	385
Sinuses	624	692
Bones and joints	3,112	3,870
Chest	6,301	6,680
Gastrointestinal tract	1,055	1,067
Gallbladder	173	177
Pelvis	151	157
Genitourinary tract	655	704
Miscellaneous	113	127
Total	12,537	[1] 13,859

[1] This figure does not include 1,188 fluoroscopic examinations. It also does not include any examinations of the spine, the figures for which are too confused to use. It is known, however, that the number of spinal examinations for 1943 exceeded 1,500.

UNIT HISTORIES

The unit histories, which follow, are presented to show the organization and caseload of the radiologic sections in large general hospitals. They are used chiefly because they are available, having been prepared from the formal official histories by former chiefs of the radiologic services in them (Halloran General Hospital, Maj. (later Lt. Col.) A. Bradley Soule, MC; Thomas M. England General Hospital, Maj. Norman Heilbrun, MC). The histories of any other general hospitals might otherwise equally well have been used.

Halloran General Hospital

Halloran General Hospital was activated on 19 October 1942 and accepted its first patients on 5 November 1942. The commanding officer was Col. (later Brig. Gen.) Ralph G. DeVoe, MC, an experienced and capable career medical officer, who proved a skillful administrator and who built up a professional staff, supplemented by a nonprofessional staff, competent to handle

the unprecedented problems inherent in a hospital of this size and with its special missions.

Mission.—Halloran General Hospital, being located close to the port of New York, had as its primary mission the reception of sick and wounded patients returned from overseas, chiefly from the Mediterranean and European theaters; the preparation of patients whose homes were not in the immediate vicinity of New York City for transfer to general hospitals nearer their homes or to the various specialty treatment centers at other Army general hospitals; and the definitive care of patients not in condition for transfer. This hospital also provided specialized medical and surgical care for patients referred from station hospitals in the greater New York area. Throughout its existence, it served as a center for orthopedic surgical patients, most of them wounded soldiers whose homes were in or near New York City. In August 1943, it was classified as a specialty center for maxillofacial surgery, plastic surgery, thoracic surgery, neurosurgery, and ophthalmology. It was also one of the several named general hospitals in the Zone of Interior in which the first studies with penicillin were carried out.

Workload.—Halloran General Hospital, often referred to as the largest Army hospital in the world, had a listed bed capacity of 3,000 plus an expansion capacity of another 3,500 beds. In February 1945, 2,650 beds were allotted for orthopedic surgery and neurosurgery (the approximately 1,700 beds set aside for neurosurgery made this the largest neurosurgical center in the world), and an additional 2,700 beds were reserved for patients evacuated from overseas for redistribution to other hospitals.

The number of patients receiving definitive care at the same time during the years the hospital operated varied from a few hundred to several thousand. During the fall and winter of 1944–45, however, when casualties were being received from overseas in great numbers—sometimes 5,000 a week—most of the beds were reserved for transients who were moved out as rapidly as possible unless their condition demanded continued care at Halloran General Hospital. Many of the transients required X-ray examinations, chiefly to check the condition of fractures and to eliminate complications of various sorts.

Officer personnel.—About a dozen medical officers were assigned to the X-ray service at Halloran General Hospital during the approximately 5 years of its operation. Capt. (later Lt. Col.) Paul T. Meyers, MC, the first chief of service, had trained at Bellevue Hospital and Memorial Hospital in New York. Lt. (later Maj.) Lloyd E. Hawes, MC, who had recently completed his residency in radiology at Massachusetts General Hospital, was assistant chief of service until he was appointed chief of the service at Rhoads General Hospital, Utica, N.Y., when that hospital was activated in August 1943. Major Soule, a professor of radiology at the University of Vermont College of Medicine, was chief of service from March 1943 until November 1945. He was succeeded by Maj. Frederick W. Van Buskirk, MC, who had trained at the University of Pennsylvania School of Medicine and the Episcopal Hospi-

FIGURE 38.—Technical personnel, Halloran General Hospital, Staten Island, N.Y., including cadre from the Army School for Medical Department Enlisted Technicians, Fitzsimons General Hospital, Denver, Colo.

tal in Philadelphia, Pa., and who had served as chief of service at station hospitals in Trinidad, B.W.I. (p. 797), and in the South Pacific before being assigned to Halloran General Hospital.

Other physicians who served on the X-ray service at Halloran General Hospital during the course of the war included Maj. Benjamin Colton, MC, who was a Board-certified radiologist when he entered the Army; Capt. Perry A. Morgan, Jr., MC, who came to the service fresh from his internship; and Maj. Robert J. Bloor, MC, Capt. James Koch, MC, Capt. Herbert S. Sharlin, MC, and Capt. Morris B. Whitman, MC, who entered service after one or more years' training in radiology. All of these officers continued in radiology after the war.

Enlisted and civilian personnel.—When the hospital was activated in November 1942, a cadre of eight enlisted men under the leadership of T3g. Emmett H. Mays served as the nucleus of the technical staff; all of them had just been graduated from the Army School for Medical Department Enlisted Technicians at Fitzsimons General Hospital. The same number of enlisted men were assigned from the hospital detachment for clerical duties (fig. 38). Late in 1943, a dozen Wacs were added to the staff, several trained as X-ray technicians and the others as clerical workers.

As the war progressed and there was need for more and more enlisted personnel for service overseas, many of the technicians and clerks assigned to the department were shipped out and replaced by civilians. During the last few months of the war, a number of those who had served overseas were attached to Halloran General Hospital for the final months of their military service. These men were now experienced and mature soldiers. Although they were anxious to return to civilian life, all of them proved responsible, able technicians, willing and even anxious to do the necessary jobs. Most of them showed a desirable and helpful sensitivity to the needs of wounded casualties because they had gone through strenuous and searing experiences themselves.

The only serious morale problem in the department arose at a time when about half of those in it were civilian employees, working under civil service and receiving salaries and perquisites considerably above those of military personnel doing comparable work. The situation was a cause of dissatisfaction and discontent. When it seemed to be reaching serious proportions, the chief of the X-ray service called the enlisted men together, explained to them why the work they were doing was, in its way, as important as any other in the Army, and pointed out that the educational and other benefits they would receive as veterans at the close of the war would more than compensate them for the higher salaries the civilian employees were then receiving. The men responded to the appeal to accept their lot cheerfully and patriotically, and there was no evidence of further discord.[3]

Protected personnel.—During 1944–45, a detachment of German prisoners of war from noncombatant units, chiefly medical (Protected Personnel) were assigned to Halloran General Hospital. Most of them had no apparent skills and were used for policing the grounds, as janitors, and in similar capacities. A few who had been trained as laboratory and dental technicians were appropriately assigned. About a dozen were assigned to the X-ray service, where some served as janitors and others assisted in the processing of films. Although several of these men had been X-ray technicians in the German Army, it was not thought wise to make use of their skills, since some U.S. patients appeared suspicious and resentful when they were worked on by men they still considered their enemies. Most Protected Personnel assigned to the X-ray service were relatively uneducated and capable of only simple

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[3] The story of one GI might be added to the more orthodox story of professional, technical, and clerical personnel. In April 1943, the need for someone with bookkeeping experience to assist with the records was met by the Medical Detachment with the assignment of a rugged young man who stated that he had been classified as a bookkeeper because he had been a bookie in civilian life. His specialized talents did not meet the needs of the position. Shortly after his assignment, after a bibulous evening, he overslept reveille, and in an attempt to avoid disciplinary action, he reported to sick call, complaining of headache and stomach distress, and was promptly admitted to the hospital. This was a time when casualties from North Africa were being shipped out in trainloads, many to distant hospitals in the United States. The day after his admission to the hospital, much to everyone's surprise, including, probably his own, the bookkeeper-bookie was shipped out, along with other patients, to a west coast hospital. Nothing more was heard of him for the next 2½ years. Then he appeared in the X-ray department at Halloran General Hospital with his chest covered with ribbons and the announcement that he had ended up in Okinawa. He was given the prodigal son's welcome, Army style.

tasks, which they performed grudgingly. Since all of them had to be kept under constant surveillance, their services made little contribution to department activities.

Facilities and equipment.—Halloran General Hospital was in process of construction as a training home and hospital for mentally defective children when it was leased to the U.S. Army for the duration of the war. A certain amount of additional construction was necessary when it became an Army hospital, including auxiliary quarters for the dental, laboratory, and X-ray services. The 40 brick and 6 wooden structures, centered about a large 6-story brick structure, were connected, for their new uses, by several miles of corridors.

Because of the expanse of the buildings and the large number of patients, it was necessary, to handle the load, to set up two separate installations for radiology service. Since most of the acutely ill patients, as well as the majority of those requiring complex radiographic examinations, such as pneumoencephalography, cerebral angiography, and bronchography, were housed in the central hospital building, the service rooms in it were planned to provide these specialized procedures. Three standard-issue 200-ma. radiographic-fluoroscopic heavy-duty units of conventional design were installed on the main floor.

The second installation, a cantonment-type building about an eighth of a mile away, housed the headquarters office of the X-ray service; a classroom where daily X-ray conferences were held with surgical and other services and where other teaching was conducted; and a large room, converted from a porch, for sorting and filing radiographs. The diagnostic rooms in this building were equipped with three radiographic-fluoroscopic machines.

Because of the half dozen or more disconnected wards for bed patients and the need to use limited personnel economically, 12 Picker field units (fig. 39) were spotted about these areas in strategic locations. One unit was located near the ward housing cardiorespiratory patients and others near wards in which orthopedic patients were in traction.

The X-ray department at Halloran General Hospital was provided with an unusually fine X-ray unit through the generosity of Greek-American citizens living in New York City, who wished to make some contribution that would assist in providing the best X-ray care for patients. During the war, however, manufacturers were turning out practically nothing but standard machines for military use and were no longer making special units. By good luck, a single deluxe prewar 500-ma. Picker diagnostic unit, equipped with serialographic spot-film device and many other accessories, remained unsold in New York. Army policy would ordinarily have prevented acceptance of nonstandard X-ray equipment, but The Surgeon General made an exception in this case. Maj. Gen. Robert C. Davis, USA (Ret.), former Adjutant General, U.S. Army, then serving as Executive Director of the New York City Chapter of the American Red Cross, and Maj. Gen. Merritte W. Ireland, USA (Ret.), former Surgeon General, U.S. Army, assisted materially in arranging details

FIGURE 39.—Demonstration of U.S. Army (Picker) field unit at Halloran General Hospital, Staten Island, N.Y. From left to right, Brig. Gen. Ralph G. DeVoe, Commanding Officer; Mr. James Picker, President of Picker X-Ray Corp.; and Lt. Col. A. Bradley Soule, MC, Chief, X-Ray Service.

of the gift, its acceptance by the Army, and its installation at Halloran General Hospital. This unit (fig. 40) was unusually versatile and was exceptionally well adapted to neuroradiologic and gastrointestinal studies and other highly technical examinations. Its acquisition permitted studies that would otherwise have been performed with less speed, precision, and effectiveness. Its usefulness proved the value of having at least one X-ray unit of the finest possible design in any general hospital designated as a specialty center in such fields as neurology, neurosurgery, thoracic surgery, cardiac surgery, and vascular surgery.

Accessory equipment and improvisations.—Although most of the X-ray equipment issued during the war was Spartan in its stark simplicity, the unfailing ingenuity of those working with it, both officers and technicians, and the U.S. love for gadgetry, produced accessories of wide variety and scope, and often of great usefulness, from bits of wood and metal.

Captain Hawes, who had been trained in the tradition of spot-film radiography in gastrointestinal studies at Massachusetts General Hospital, designed a simple but most effective device which slipped over the fluoroscopic screen and held an 8- by 10-inch cassette in position to be moved easily into the field for rapid radiography. There were no relays for rapid changeover, but an

FIGURE 40.—Dedication of 500-ma. X-ray unit given to Halloran General Hospital, Staten Island, N.Y., by Greek-American citizens of New York City.

alert technician at the controls, when the signal was given, quickly raised the milliamperage from fluoroscopic low to radiographic high. The exposures were phototimed in the mind of the radiologist, who coordinated his vision with his foot switch. In spite of the crudity of the system, some exceptionally beautiful spots of ulcers, carcinomas, disk defects, and spinal cord tumors were produced by it.

During the second and third years of its operation, the X-ray department at Halloran General Hospital had the good fortune to employ a civilian, Mr. John Eno, as a combined technician-serviceman and general jack-of-all-trades. He had worked for several small X-ray equipment manufacturing firms, and he possessed a basic general knowledge of electricity and machine design, as well as some knowledge of electronics. He was a competent fabricator of equipment, and he was handy with a lathe and other machine tools. He was, therefore, able to design and construct a number of fairly complex pieces of equipment, including a rapid cassette changer for cerebral angiography (fig. 41). He also serviced most of the machines, and when he was not otherwise engaged, he lent a hand at almost any task in the department that had to be done.

Several enlisted men who had been trained as technicians at Fitzsimmons General Hospital also proved adept at improvising equipment from odds and ends. Sgts. Frederick Fick, Lyle Jennings, and Howard T. Sigmund

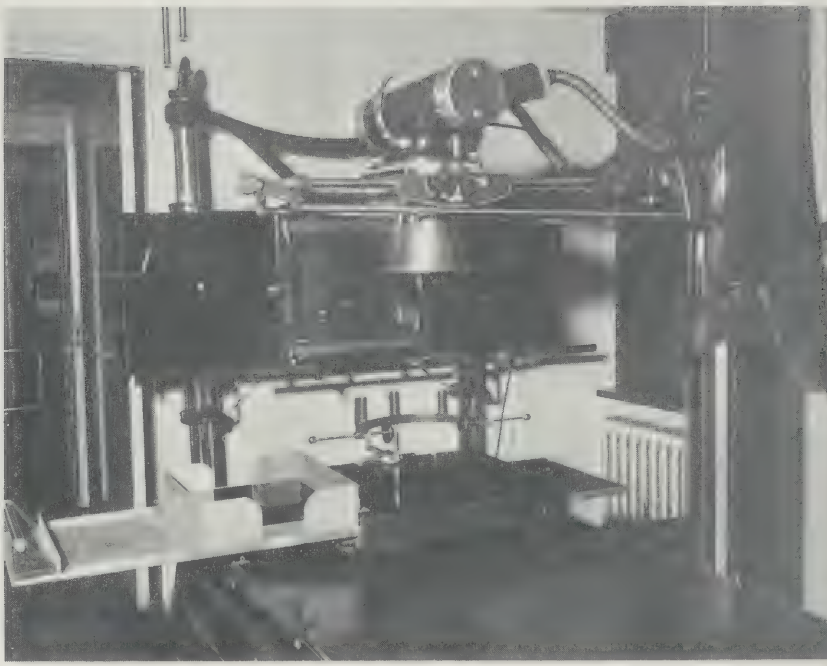

FIGURE 41.—Improvised rapid cassette changer for cerebral angiography, Halloran General Hospital, Staten Island, N.Y.

constructed such items as cassette tunnels for bedside radiography, a chair and headholding device for pneumoencephalography (fig. 42), and even a rather complicated planigraphic attachment which allowed radiologists to obtain excellent body section radiographs.

Storage and disposition of films.—The enormous number of patients handled at Halloran General Hospital required the setting up of a rather elaborate system of records, to solve the special problems of the hospital population. Almost all of the patients were received by ship from overseas, and most of them were evacuated, as promptly as possible, to other hospitals in the Zone of Interior for definitive care. Something of the magnitude of the load has been pointed out elsewhere (p. 146), including the fact that, during the fall of 1944, an average of 5,000 patients per week arrived at the hospital, most of whom were transferred out of it within a few days.

In most instances, X-ray films of arriving patients were received in manila envelopes, inscribed with their names and serial numbers, and with copies of the X-ray reports glued to the face of the envelopes. With each group of casualties came large bundles of these envelopes (on occasion tons), which were dumped in the entrance of the X-ray building. The entire department, often officers and technicians as well as clerical workers, then set to work

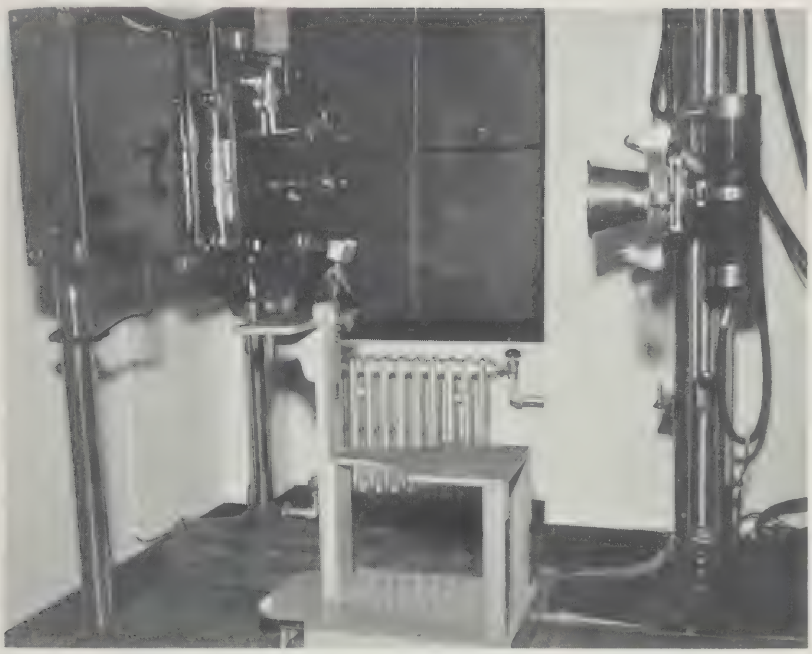

FIGURE 42.—Improvised chair and headholder for pneumoencephalography, Halloran General Hospital, Staten Island, N.Y.

sorting the envelopes by dropping them into appropriate alphabetical slots. Over the months, it was found that identification was speedier and more accurate if classification was by the patients' last names; when names were similar, first names and serial numbers were also used. The entire project, which was conducted under the supervision of two Wacs, T5g. Gertrude Hunt and T5g. Annie M. Lawson, was carried out on a large porch of Building 75, which was converted into a fileroom (fig. 43).

The principal difficulty in this project was encountered when films did not arrive on the same ships as the patients, but came later. If the patients had been transferred to other hospitals, as not infrequently happened, a time-consuming search was required to determine whether the films had ever arrived and, if they had, what disposition had been made of them.

Radiographs of patients held for definitive care were filed in a separate area. If they were loaned to wards in other buildings, tracer cards, with pertinent information, were placed in the spaces in which they were filed.

When the X-ray department received notice of the pending shipment of patients to other hospitals, the names of the patients on the order sheet for each hospital were checked against the files, and the films which had arrived with the patients (as well as those taken after their arrival) were tied together and sent with them. The letter of transmittal to each hospital

FIGURE 43.—Film fileroom, Halloran General Hospital, Staten Island, N.Y.

included a copy of the orders, with checks against the names of patients whose films were being shipped.

Early in 1945, when the volume of films and records arriving and leaving the hospital amounted to heroic proportions, a separate records division was set up outside of the X-ray service. The experience they had gained in the handling of films during the preceding 3 years proved invaluable to those in charge of the new division.

In retrospect, it would have been wiser and more economical of personnel if this entire project had been handled from the beginning outside of the X-ray service, by clerical help trained and experienced in postal methods. If a similar situation arises in the future, it is suggested that this method be used. It is also recommended that films and other records not readily identified at receiving hospitals be sent to a central clearing agency that has access to names and addresses of all Army personnel.

Conferences and training program.—Each weekday morning at 0800 hours, members of the surgical service met in the conference room of the X-ray service, where one of the radiologic staff presented the films of all surgical cases examined the day before. As each patient's name was called, his ward officer gave a brief summary of the case, after which the radiologist

in charge of the conference presented the patient's early films and the films just taken, and offered his interpretation. These conferences, which were instituted at the suggestion of the Chief, Surgical Service, Lt. Col. (later Col.) Vansel S. Johnson, MC, served a number of useful purposes:

1. They kept the chiefs of the service and of other sections informed of the X-ray findings of all patients on the services.

2. They enabled the ward officers to examine new radiographs of their patients before they made daily rounds.

3. In problem cases, they provided the opportunity for immediate mass consultation.

4. They served as an intensive educational course in radiologic interpretation, which was of great value to all those who attended and participated. Because of the large numbers of patients who passed through the hospital, numerous interesting and unusual forms of disease and injury were available for study. Orthopedic cases predominated, but many other conditions were observed, such as brain tumors, abscesses and aneurysms, bronchogenic neoplasms, foreign bodies in the heart and lungs, peptic ulcers, gastrointestinal neoplasms, and even some of the rare exotic diseases from many parts of the world. Since there were many experienced teachers from medical schools on the hospital staff, the large group of young physicians who had just completed their internships or residencies could profit by, and participate in, the lively discussions which often ensued at these conferences and which reflected the high quality of care rendered to the patients.

The conferences held weekly for officers on the medical service were used almost exclusively for teaching purposes. The carefully selected cases presented provided for broad discussions of pathologic processes, diagnostic criteria, and therapeutic methods. Many of the presentations concerned conditions infrequently observed in the eastern United States. The large volume of material and its sources, which were frequently foreign, permitted the study of such conditions as filariasis, echinococcus cysts (fig. 44); leprosy (fig. 45); sarcoidosis with both bone (fig. 46) and pulmonary (fig. 47) changes; histoplasmosis, coccidioidomycosis with both bone (fig. 48) and pulmonary (fig. 49) changes; and collagenous diseases.

Frequent lectures, symposia, teaching ward rounds, and short courses on various subjects were held at Halloran General Hospital through the cooperation of medical schools and hospitals in the area and the services of members of the hospital staffs and professional consultants. They were all interesting and stimulating, as well as profitable, to members of the staff and reflected in the excellent care the patients received.

Several special courses were given to medical officers at the hospital. Outstanding among them was the lecture course in neuropathology in the spring of 1945 by Dr. Abner Wolf, Professor of Neuropathology, College of Physicians and Surgeons, Columbia University. The emphasis was on the clinical implications of this subject, and the course was therefore of special

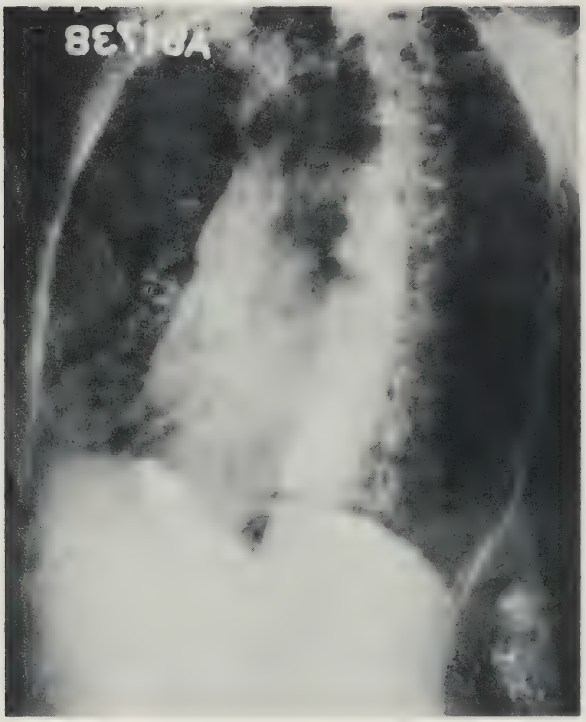

FIGURE 44.—Calcified hydatid cysts in right lower lung and right lobe of liver.

interest to neurologists, neurosurgeons, pathologists, and radiologists. The lecture hall was filled to overflowing with attentive, interested listeners at each session.

The hospital staff served as host to many local and regional, and a few national, professional societies, and presented programs before them based largely on the patients there under treatment. Maj. Champ Lyons, MC, who directed the penicillin study at the hospital, presented his material on several occasions to members of the hospital staff and others. The radiologic service participated actively in all of these presentations.

Scope of work.—The special missions of Halloran General Hospital changed several times during its 5 years of operation, and the kinds and numbers of X-ray examinations reflected these changes. Throughout the whole period, the large numbers of orthopedic patients required a high proportion of examinations of the long bones and spine. During the year ending in December 1943, 25 percent of X-ray examinations were of long bones and 9 percent were of the spine. Chest examinations, many of them routine, accounted for 37 percent and gastrointestinal studies for 9 percent. The

FIGURE 45.—Destruction of distal metatarsals and proximal phalanges caused by leprosy.

remaining 22 percent was divided among other parts of the body, chiefly the skull, sinuses, mastoids, and abdomen.

When large numbers of casualties began to arrive from Europe in 1944, many bedside examinations were required to check the condition of patients with compound fractures of long bones and with wounds of the chest, abdomen, and spine. When Halloran General Hospital was designated as a major neurosurgical center in 1945, large numbers of highly specialized procedures, such as myelography, pneumoencephalography, and cerebral angiography, became necessary. At one time, over 700 patients with suspected herniated nucleus pulposus were in the hospital at the same time, and as many as 30 myelographic examinations were performed each working day, by a routine developed to expedite the procedure (p. 163). Angiography and pneumoencephalography were facilitated by the use of accessory equipment, much of which was improvised.

The experience at Halloran General Hospital indicates that, in a future conflict, general hospitals called upon to perform large numbers of specialized procedures should be equipped with high milliamperage X-ray machines with motor-driven tables; well-built, sturdy serialographic units; and other accessories designed to permit taking unusual and difficult projections at high speed.

The observation of large numbers of patients in an intellectual climate unusual for a military installation functioning under wartime conditions stimulated the officers stationed at Halloran General Hospital to prepare a number of significant contributions to the military literature. A number of these were from the radiologic service and dealt with such subjects as myelography in herniations of the intervertebral disk; bone and joint changes in paraplegia; leptomeningeal cysts; acromioclavicular dislocations; mutational dysostosis; and pulmonary changes in achalasia (p. 170). A number of exhibits

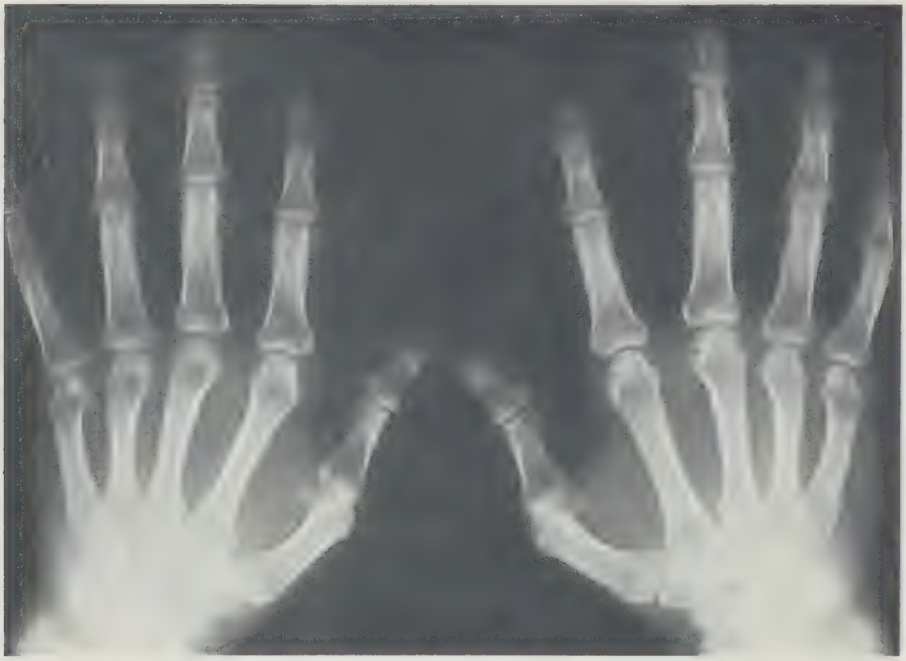

FIGURE 46.—Cystic sarcoid bone changes in base of first metacarpal and navicular on both sides.

were presented on these and other subjects at regional and national medical meetings.

Thomas M. England General Hospital [4]

England (later Thomas M. England) General Hospital did not assume the status of a general hospital until 15 August 1943. Previously, it had been an Army Air Forces hospital, and it was taken over by the Second Service Command after the Air Forces no longer needed it as a basic training center. Eventually, the hospital occupied Chalfonte-Haddon Hall, the Traymore, and several other hotels in Atlantic City. Haddon Hall, the first hotel to be occupied, was a luxury hotel, and Major Heilbrun, MC, Chief, Radiology Section, Thomas M. England General Hospital, described his sensations when he reported for duty there, just 3 months after he had been a guest at the hotel during a meeting of the American Medical Association. It had been stripped of every piece of furniture and all carpeting, and every room was bare to the walls.

Since there was no X-ray equipment on hand, Major Heilbrun was assigned to the surgical service and assisted at the first operation, in an improvised operating room.

[4] The material for this account was supplied by Dr. Norman Heilbrun.

FIGURE 47.—Widespread pulmonary sarcoidosis affecting both parenchymal area and hilar nodes.

The space selected for the X-ray department had been part of the large lounge area on the mezzanine floor of the hotel. Plans for it were drawn up with the help of the technical staff of the General Electric X-Ray Corp., whose equipment was to be used. One problem was how to protect the marble floors and ornately decorated columns. It was solved by building protective wooden walls around the columns and by laying false floors, under which all conduits and pipes were located. The darkroom was located next to an unused elevator shaft, up which the plumbing for it was brought. Permission to cut a hole in the floor for a toilet to serve the radiographic room was denied at first but was quickly granted when it was pointed out that a patient being studied by barium enema might have difficulty reaching the nearest toilet, some 70 feet away. Pass boxes were not available; they had to be designed and built, along with the special hardware necessary to make them lightproof.

The first patients entered the hospital in August 1942, but the X-ray department did not begin to operate until December of that year. The principal reason for the delay was inability to obtain transformers appropriate for the alternating current supplied by the local power company. Only direct current was available from the powerplant of the hotel, and it would have required rotary converters.

The organization of the X-ray department was accomplished without special difficulty, but providing for enlisted technicians was another matter.

FIGURE 48.—Typical bone lesions of coccidioidomycosis at lower end of tibia.

Only one or two of those assigned to the department had had any training in this work, and no men were then available from any of the training courses. On-the-job training was therefore necessary.

The physical layout of the hospital was conducive to efficient radiologic service. The beds were concentrated in the two large hotel buildings, which were connected by a bridge, and elevator service in both was excellent. Any patient in any part of the hospital could therefore be brought to the X-ray department within 5 to 10 minutes and returned to his ward in the same time.

In September 1944, a hurricane struck Atlantic City and caused a complete breakdown of all service, including electrical and plumbing services. The hospital had to be evacuated within 24 hours, and planning and the implementation of the plans required many hours of organization and teamwork. There was no elevator service, and there were patients on all floors above the ground level. The several hundred nonambulatory patients all had to be evacuated by litter, and all orthopedic patients in traction had to be put into plaster casts before they could be moved. It was 6 weeks before all electric equipment, such as motors and transformers, which had been

Figure 49.—Widespread pulmonary coccidioidomycosis. Note some lesions show cavitation.

damaged by sea water, could be repaired and the hospital reopened. In the meantime, limited power for X-ray and other services was provided by emergency portable generators.

Thomas M. England General Hospital, in addition to its functions as a general hospital, became a specialty center for amputees and for neurological and neurosurgical casualties. Its facilities continued to expand until it had a capacity of approximately 5,000 beds, of which 2,800 were active and 2,200 were for convalescent patients. The enlargement required an increase in radiologic equipment from two units to four. Intermediate X-ray therapy was also provided during the expansion.

The first battle casualties received at the hospital were transfers from Halloran General Hospital. As the population increased, the great majority of patients were combat casualties. The hospital also served the general medical and surgical needs of the various other commands stationed in or near Atlantic City.

While the hospital operated as an Air Forces hospital, its duties were those of a busy station hospital. Because of the rigorous physical training required in the inclement weather of the winter and spring of 1942–43, patients with viral pneumonia were observed in large numbers.

Special clinical conditions encountered at this hospital, and the studies made of them, are described elsewhere in this chapter.

Section II. Technical Considerations

Basic techniques were used in all named general hospitals, and Colonel Kirklin and other consultants who inspected departments of radiology in them had few adverse comments on the quality or the quantity of the output. Many refinements of technique, however, and some new techniques were introduced during the war, and a few of them might be mentioned.

TECHNIQUES

Optimum kilovoltage technique.—Maj. Arthur W. Fuchs, SnC, devoted a good deal of time and attention to improvement and standardization of techniques to be used with Government-issue equipment (*6*, *7*). The optimum kilovoltage technique which he developed was based on reduction of exposure factors, except milliampere seconds, a technique which proved as precise as it was simple. Since it required very little effort on their part, better than average films could be produced even by student technicians.

Major Fuchs also developed a modification of this technique for examination of the chest. The technique required the use of a generator capable of delivering 100 kilovolt peaks at 200 milliamperes, though 150 milliamperes was recommended, to conserve tube life. Since the use of a constant setting of 100 kilovolts produced an overabundance of secondary radiation, the use of a stationary grid was recommended. Depending on the thickness of the chest, a time exposure of 0.2, 0.3, or 0.4 second was used. This technique was simple and economical of time of personnel as well as of material and equipment, and it produced films of high quality and great diagnostic accuracy.

Major Fuchs prepared the technique chart issued with every Army field unit. Instructions were based on the thickness of the part to be examined. Images were provided in which detail of both bones and soft tissues were visible, with no areas of underexposure or overexposure. These results were accomplished with a long scale of contrast and a minimum of fog from secondary radiation.

Densitometry.—At Percy Jones General Hospital, Lt. Col. Joseph C. Bell, MC, and Maj. (later Lt. Col.) Gilbert W. Heublein, MC, made studies with the Morgan-Hodges exposure meter (fig. 50), a device that takes advantage of the fact that all properly exposed films are of an average density of 0.9 in the diagnostic range as read on a densitometer, regardless of the part of the body examined (*8*). The detector unit is then replaced by a film which is exposed according to the previously determined exposure time.

Results with this device were excellent, and all instances of failure were attributable to improper positioning of the detector unit. Particularly good results were obtained in examination of amputation stumps in which considerable demineralization had occurred and in other examinations in which bone condensation changes or calcification of soft tissues made determination of

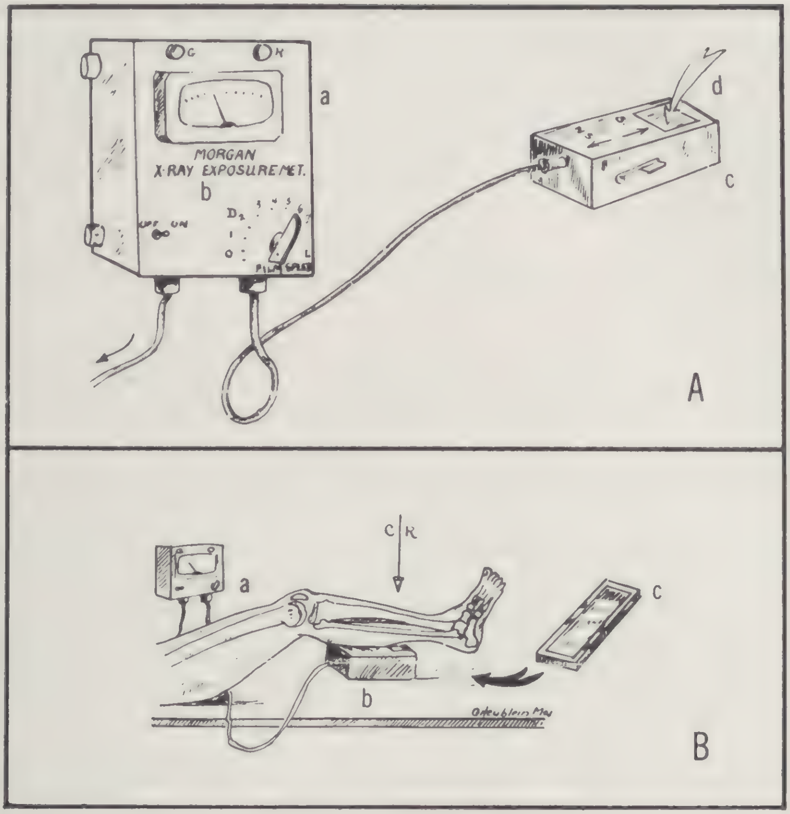

FIGURE 50.—Morgan-Hodges radiographic exposure meter, Percy Jones General Hospital, Battle Creek, Mich. (8). A. Components of apparatus: Meter unit (a), X-ray exposure meter (b), detector unit (c), and detector screen (d). B. Method of use: Meter unit (a), detector screen (b), and film in cassette (c).

proper exposure difficult by ordinary measurements. Clarity of detail was notable in orthopedic cases in which films had to be made through plaster. Much more uniform exposures were obtained in followup films made by this technique than when reliance was placed on measurements made by different technicians. Film densities were found to remain constant over a wide range of kilovoltages.

Myelography.—At Halloran General Hospital, as already noted, the large numbers of myelographies to be performed required an efficient routine. Before the service grew so heavy, the injection and removal of Pantopaque were performed by the neurosurgeons. Later, it was found that young ward officers, recently out of their internships, could be trained to perform these procedures skillfully and safely, thus releasing neurosurgeons for other duties. The Pantopaque was injected intraspinally with the patient prone on the

wheeled litter on which he had been brought to the X-ray department. He was then moved to the X-ray table, where fluoroscopy was carried out and spot and overhead radiographs were taken, after which the contrast medium was removed under fluoroscopic control.

At DeWitt General Hospital, a somewhat similar plan was used. As many as 14 lumbar myelograms were sometimes made each afternoon, with 3 diagnostic rooms in use. The ward officers on the neurosurgical wards performed the lumbar punctures and introduced the Pantopaque, while the radiologists went from room to room, making the fluoroscopic studies and spot films and returning for the removal of the opaque medium.

Chest examination.—At Lovell General Hospital, Capt. (later Maj.) Gerald Lavner, MC, and Maj. (later Col.) Benjamin Copleman, MC, recommended anteroposterior lordotic projections of the chest as an extremely useful technique for the detection and identification of small or inadequately visualized lesions in the pulmonary apex (*9*).

Bronchography was used routinely, but as Lt. Col. Samuel I. Kooperstein, MC, and Maj. Hyman E. Bass, MC, showed, it was not entirely free of risk (*10*). They made intensive studies of the opaque media used for this purpose after they had observed three patients with bilateral basal pulmonary densities following intrabronchial instillation of Lipiodol; all three were known asthmatics. The authors emphasized the importance of skin testing of all patients before bronchography, especially those with allergic backgrounds.

Pneumoarthrography of the knee.—Among the techniques described for air injection of the knee, for the demonstration of fractures of the menisci and other lesions of the joint, was the method described by Maj. Jack W. Grossman, MC, and Capt. (later Maj.) Howard H. Minor, MC (*11*). It showed a particularly satisfactory degree of correlation between radiographic and surgical findings.

Urinary tract techniques.—At Thomas M. England General Hospital, Major Heilbrun and Maj. George E. Chittenden, MC, emphasized the value of the 24-hour delayed urogram, particularly in patients with ureteral obstruction (*12*). In several of their patients the point of obstruction was demonstrable only on 24-hour films.

At Percy Jones General Hospital, Colonel Bell, Major Heublein, and Maj. (later Lt. Col.) Howard J. Hammer, MC, studied the complementary role of intravenous and retrograde urography and pointed out the value of roentgenoscopy and of radiographs in the lateral projection in the detection of obscure lesions (*13*). In this department, the technique was adapted to the needs of the individual patients, though a preliminary scout film of the entire tract, before injection, was routine. The radiologist himself directed the procedure and gave the injection. Retrograde examinations were done in the department of urology but under the direct supervision of the radiologist. The details of this technique are well worth careful study.

Venography.—At Letterman General Hospital, Capt. (later Maj.) Allison E. Imler, MC, and his associates studied selected patients with varicose veins by venography (*14*). They found the technique of special value in the detection of deep venous pathologic changes otherwise not demonstrable.

Examination of the colon.—At Ashford General Hospital, Lt. Col. Robert C. Pendergrass, MC, and Capt. (later Maj.) Frederick W. Cooper, Jr., MC, suggested the use of rubber bulbs, such as those supplied with Asepto syringes, in studying the colon after colostomy (*15*). The neck of the bulb was strapped firmly into the colostomy stoma and the enema tube was inserted through the bulb.

Localization of intraocular foreign bodies.—The Sweet method of localization of intraocular foreign bodies was generally favored in named general hospitals. At Halloran General Hospital, however, a comparative study showed the Comberg contact method of Pfeiffer to be more consistently accurate. Small foreign bodies in the cornea or the anterior portion of the globe, even those with low opacity such as bits of glass, frequently could be detected by soft-tissue radiographs on dental films held close to the root of the nose near the inner canthus of the eye.

A number of hospitals used the ring method of localization, devised by Capt. Edward W. Perkins, MC, at the 45th General Hospital, Naples, Italy (*16*). It required the fabrication of three rings of 18-gage round silver wire, 24, 25, and 26 mm., respectively, in diameter. Under topical anesthesia with 1 percent Pontocaine (tetracaine hydrochloride), whichever of the rings best fitted the glove was fitted snugly around it at the equator. A small groove in the wire was placed at the external canthus. Four exposures were made, a posteroanterior view in the Waters position, with the patient looking straight ahead, and three lateral projections, with forward, upward, and downward gaze. The location of the foreign body was determined by its position in relation to the ring. In practice, this technique proved more reliable than the Sweet method (p. 275).

Fluoroscopy.—Reduction of fractures under the fluoroscope was officially discouraged (*17*) and was practiced in only a few hospitals. No matter how helpful some orthopedic surgeons might consider this method, it occasionally resulted in irreparable damage to the hands and arms. Moreover, when an X-ray department was properly run, there was no need for it. When the department, or some section of it, was located near the operating room, or the orthopedic wards, the position of bone fragments could be checked within a few minutes. At Thayer General Hospital, where a special warm solution was devised by one of the technicians, films were back in the operating room 3½ minutes after the picture had been made.

An occasional request for a hand fluoroscopic screen to check the position of fractures on orthopedic wards was invariably refused. The hazards of its use simply did not balance the information secured from it.

MAP 1.—Areas of world from which patients were received at Percy Jones General Hospital, Battle Creek, Mich., in 1943 (*8*).

Section III. Clinical Studies

GENERAL CONSIDERATIONS

World War II differed from all previous wars in that many thousands of men who would formerly have died on the battlefield survived to reach frontline hospitals, and many thousands survived in frontline hospitals to reach hospitals in the rear and, later, in the Zone of Interior. The unprecedentedly high rate of survival explains why general hospitals in the Zone of Interior received so many combat casualties with such a wide variety of wounds, wounds whose clinical course and outcome were so often altered by the use of penicillin and other antimicrobial agents. These general hospitals, as has also been indicated, received patients from all over the world (map 1) with diseases not seen in the United States, or not seen in their current manifestations. Finally, these hospitals received patients from station and other hospitals in the service commands in which they were located with serious and obscure conditions. The medical officers attached to these general hospitals had an unparalleled clinical experience, and radiologists played an active part in it.

The range of conditions observed was incredibly wide, varying from an occasional march fracture—injuries of this kind did not often reach general

FIGURE 51.—Calcification adjacent to adductor tubercle typical of Pellegrini-Stieda disease.

hospitals—to neoplasms of extreme rarity. An idea of the variety of conditions encountered on the radiologic service of a busy general hospital can be gained by listing the conditions mentioned in the Preston M. Hickey Memorial Lecture for 1944, which was based on the diagnostic experience in the department of radiology at Percy Jones General Hospital (*8*). It included:

1. Cerebral trauma of all kinds, with every conceivable complication, as well as tumors of the brain and pituitary gland. Many of these conditions were studied by special techniques, including encephalography.

2. Herniated nucleus pulposus; fractures and other spinal injuries; juvenile epiphysitis (Scheuermann's disease); and spondylolisthesis. Many of these conditions were studied by special techniques, including myelography.

3. Injuries and diseases of the accessory sinuses and facial bones, many of them requiring special techniques of examination.

4. Injuries of the bones and joints of innumerable varieties and with a wide variety of complications; tumors of the bone, such as endothelial myelomas and osteogenic sarcomas; cystic disease secondary to parathyroid tumors; metastatic lesions; the arthritides, including traumatic arthritis and Marie-Strümpell disease; osteochondritis dissecans; Pellegrini-Stieda disease (fig. 51); and recurrent dislocations.

5. Atypical pneumonia and its complications, such as empyema and bronchiectasis; hemothoracic empyema; bronchopleural fistula; coccidioidomycosis; Hodgkin's disease of the mediastinum; Boeck's sarcoid; blastomycosis; and carcinoma. Many of these conditions were studied by bronchography.

6. Diverticula and peptic ulcer of the esophagus; cardiospasm; diaphragmatic hernia; duodenal and gastric ulcers; deficiency states with small bowel manifestations; intestinal obstruction; and polyps and carcinoma. All these cases were studied, as indicated, by barium meals, barium enemas, esophagoscopy, gastroscopy, and other diagnostic means.

7. Urinary calculi, which were surprisingly frequent and which were preexistent in many cases; lesions on a congenital basis, such as pyelectasis, obstructions, neoplasms, and retroperitoneal metastases with urinary tract involvement from testicular tumors. These conditions were studied by special techniques of urography.

8. Foreign bodies in all parts of the body, including the eye.

The conditions listed were typical of those seen in most general hospitals in the Zone of Interior. They provided the radiologists in them unusual opportunities not only to see both common and uncommon conditions but also to study them in a way frequently not possible in even leading teaching hospitals because of the regulation that patients in military hospitals were to be discharged only after they had attained maximum improvement, a status which might require hospitalization for weeks and months.

A report by Maj. (later Col.) Lucien M. Pascucci, MC (*18*), from O'Reilly General Hospital in the Seventh Service Command, called attention to the many patients who were hospitalized with chronic diseases which could have been identified before induction—and would have been a cause for rejection—if the screening process had been more careful and radiography had been employed more frequently. Among these conditions were bronchiectasis, urinary calculi, posttraumatic atrophy of the brain, herniated intervertebral disk, spondylolisthesis, duodenal and gastric ulcers, and colitis. Major Pascucci emphasized the need for more attention to such symptoms and signs as cough, injuries of the head and spinal column with subsequent pain on activity, and digestive disturbances. He warned, however, that the wider application of specialized radiologic procedures, such as bronchography, intravenous urography, encephalography, myelography, and similar techniques, could be justified only when they were performed by trained personnel.

Many of the techniques developed and many of the conditions observed in named general hospitals in the Zone of Interior were reported in the literature during and immediately after the war. In addition to technical reports (p. 162), these contributions can be roughly classified as:

1. Articles dealing with the radiologic aspects of medical and surgical problems peculiar to military medicine.

2. Articles of a general nature, not specifically related to the military experience.

3. Case reports.

As a matter of convenience, the reports briefly summarized in the following pages are discussed under clinical-anatomic headings. The list is representative but not complete.

CHEST

Atypical pneumonia.—Atypical pneumonia was observed with great frequency in epidemics of respiratory disease in general hospitals in the Zone of Interior. In some, the incidence was as high as 25 percent. At Thomas M. England General Hospital, about 8 percent of the patients showed delayed resolution, and bronchographic studies showed bronchiectasis to be present. Unfortunately, preinduction films were not usually available, and it was therefore seldom possible to determine whether this condition was the result of the pneumonia or was preexistent. Other complications reported were pleuritic involvement (*19*), often the result of too brief a convalescent period, and fracture of the ribs. Maj. (later Lt. Col.) Rolfe M. Harvey, MC (*20*), reported 18 such fractures, half of them multiple, in 500 consecutive cases of atypical pneumonia. The fifth and sixth ribs were most commonly affected, followed by the fourth, seventh, eighth, and ninth ribs in that order. All the fractures were in the anterior or midaxillary line. All were attributed to coughing and were thought to be the result of repeated small injuries of a subthreshold nature, similar to march and other types of stress fractures.

Fungus disease.—Military service in certain desert sections of the southwest United States, especially California, proved hazardous as regards exposure to certain types of fungus disease, particularly coccidioidomycosis. Patients were usually referred to general hospitals from station hospitals in the vicinity and several representative groups were studied. Capt. Vernon L. Peterson, MC (*21*), observed 24 patients at Winter General Hospital, Topeka, Kans., and found a variety of lesions, the most frequent being a solitary nodose infiltrate that later broke down, leaving a thin-walled cavity. When these lesions were multiple, they sometimes resembled metastatic carcinomas and sometimes tuberculous lesions. Pleural involvement was observed in several cases, and about half of the patients studied showed slight enlargement of the hilar nodes. At Percy Jones General Hospital (*8*), it was found necessary to bear coccidioidomycosis constantly in mind whenever any bizarre type of pulmonary lesions, whether atypical or basal, was encountered and to inquire regarding the skin test, which usually became positive some time during the third week.

Two types of the disease were observed on roentgenologic examination. In the first type, which was relatively benign and was designated as the primary phase, there were nodular areas of increased density or atypical, somewhat pneumonic-like consolidation in the lung fields, not unlike those observed in atypical pneumonia. The thin-walled cavities often present usually closed spontaneously. The secondary or granulomatous phase, which was highly

fatal, was characterized roentgenologically by chronic fibrotic pulmonary changes, with and without cavitation. The bone lesions likely to occur during this phase had a bizarre distribution and showed a predilection for pressure points, such as the malleoli, the acromion processes, and the olecranon. Miliary dissemination was not infrequently a terminal manifestation.

Observations at Bushnell General Hospital emphasized much the same points in the patients treated there, most of whom came from the training center in the San Joaquin Valley, Calif. Attention was called to the coalescence of nodules, which sometimes resulted in a consolidated lung, and the chronicity of the associated bone lesions. Generally speaking, the larger numbers of cases of coccidioidomycosis at regional and station hospitals, such as the several hundred studied by Lt. Col. Horace W. Jamison, MC, at the Army Air Forces Regional Hospital at Santa Ana, Calif., presented much the same features (*22*).

Captain Peterson also studied several patients with actinomycosis at Winter General Hospital (*21*). The disease was extensive and was sometimes associated with abscess formation and, less often, with diaphragmatic penetration and extension to the liver.

Aspergillosis at this hospital ran a much more benign course. The typical lesion was soft, irregular, peribronchial or parenchymal infiltration with enlargement of the regional lymph nodes. *Monilia albicans* infection was frequent, usually as a secondary process, with pulmonary infiltration and adenopathy characteristic. Torulosis and blastomycosis were uncommon. Captain Peterson pointed out that a single roentgenologic study furnished no specific criterion for the diagnosis of any of these fungus diseases, but that the radiologist who was familiar with the findings could often suggest the probable condition present.

Aspiration pneumonia.—At Halloran General Hospital, Captain Hawes and Major Soule (*23*), in a study of pulmonary changes in cardiospasm, called attention to the frequency with which chronic pulmonary disease resulted from repeated aspiration of esophageal contents in achalasia and cardiospasm. Maj. (later Lt. Col.) Oscar N. Mayo, MC, and Maj. (later Col.) Jack Spencer, MC (*24*), made the same observation at the Fort Bliss Station Hospital.

GASTROINTESTINAL AND RELATED SYSTEMS

Peptic ulcer was a relatively frequent condition in general hospitals. At Oliver General Hospital in 1943, about 30 gastrointestinal examinations were made each week and from 20 to 25 percent of the yearly total were positive for ulcers, most of them duodenal and most of them diagnosed before the patients were sent to this hospital. Of the 118 gastrointestinal examinations made in October, November, and December 1944, 36 were positive for ulcers, 35 of which were duodenal. No instances of carcinoma of the stomach were found. The patients subjected to gastrointestinal study represented a selected proportion of the 10 to 20 percent of patients on the medical wards with diges-

tive complaints, a large number of which were functional. It was found that the administration of phenobarbital and belladonna before the examination permitted better visualization of the stomach. Results were also better in gallbladder studies when the same technique was used.

At Walter Reed General Hospital, Major Hinkel (*25*) called attention to the fact that, in certain cases, localized hypertrophic gastritis with polypoid or adenomatous changes must be carefully considered in the differential diagnosis of gastric tumors, in which carcinoma must also always be considered.

A number of interesting case reports were made. Colonel Present (*26*) observed two cases of aberrant pancreas at Hoff General Hospital, one intramural and the other polypoid but both in the gastric antrum. Of the 410 cases of aberrant pancreas reported in the literature, about a quarter were in the stomach and another quarter in the duodenum. Lt. Col. Ray B. McCarty, MC, and Major Present (*27*) reported from the same hospital a mesenteric pouch hernia simulating a paraduodenal hernia. The presenting symptoms were highly suggestive of volvulus.

SPINE

The spine was studied intensively, both by plain films and by myelography. One of the most interesting and surprising general studies, conducted by Maj. Murray M. Friedman, MC, Maj. (later Lt. Col.) Frederick J. Fischer, MC, and Capt. Robert E. Van Demark, MC, covered 100 healthy soldiers 19 to 39 years of age (*28*). With few exceptions, the whole group had had strenuous military training and some had been in combat, but none of them had ever had a backache or had suffered a back injury. Yet in only 20 of the group were the findings on plain films entirely normal. The commonest abnormalities were asymmetrical facets in 39 cases; spina bifida occulta in 36; transitional vertebrae and narrow lumbosacral joints in 11 each; Schmorl's nodes in 8; spondylolisthesis and spondylolysis in 6; and arthritis of the lumbosacral or sacroiliac joints in 5. Anteroposterior, lateral, and oblique roentgenograms were made, as well as a single anteroposterior film with the tube tilted 30° cephalad.

At Nichols General Hospital, Maj. Anthony C. Galluccio, MC (*29*), analyzed 142 routine studies of the lower spine, finding in them 15 instances of prespondylolisthesis or spondylolisthesis. In 35 additional examinations, he found 20 instances of prespondylolisthesis, 17 of which were bilateral, and 15 instances of spondylolisthesis. This incidence was much higher than had been generally reported. Major Galluccio emphasized the importance of the quality of the films, which were made in the anteroposterior, right and left oblique, and true lateral positions. He also called attention to the importance of being alert to this condition because of its progressive character and its possible medicolegal importance. It was also studied intensively in the Mediterranean theater (p. 308) and in the Southwest Pacific Area (p. 671).

At Oliver General Hospital, an instance of phosphorus poisoning was observed in a Negro soldier who stated that, in his youth, he ate match heads. Various lines of epiphyseal growth were evident on the roentgenograms, and the films of the spine looked like double exposures.

Pantopaque myelography.—Pantopaque had been introduced for myelography shortly before the war, and there was general agreement as to its value for this purpose. In their studies at Halloran General Hospital, Major Soule, Capt. (later Maj.) Sidney W. Gross, MC, and Capt. (later Maj.) James G. Irving, MC (*30*), reported that its low viscosity made injection and removal easy, and since no force was required to inject it there was less chance that it would enter the epidural space.

At Walter Reed General Hospital, Captain Wyatt and Lt. Col. (later Col.) R. Glen Spurling, MC (*31*), studied six patients in whom 3.5 cc. of Pantopaque was injected into the lumbar subarachnoid space and left in situ. When subsequent studies were made of the skull and entire spine at intervals of 9 to 15 months later, estimates of the residual medium varied from 0.1 to 1.5 cc. There were no symptoms referable to its retention.

Diagnostic accuracy was high with Pantopaque myelography. At Ashford General Hospital, 69 of the 215 patients studied by Lt. Col. George L. Maltby, MC, and Colonel Pendergrass (*32*) were surgically explored. Of the 60 with positive findings, 54 were found to have disk lesions. Of the nine operated on with negative X-ray findings because of what seemed to be classical clinical findings, five were found to have no lesions. These same authors also described myelographic findings in patients with varices, adhesions, and epidural abscess.

Similarly accurate findings in a smaller number of cases were reported from O'Reilly General Hospital by Lt. Col. Francis Murphey, MC, and his group (*33*). These observers also emphasized the continued value of plain films in studies of the spine, particularly the presence of scoliosis, straightening or reversal of normal cervical curves, calcification in the posterior joint spaces, encroachment on the intervertebral foramina by soft tissue or osteophytes, and localized arthrosis.

At Lovell General Hospital, Major Copleman (*34*) demonstrated five instances of small central protrusions of lumbar disks. He pointed out the importance of careful fluoroscopy in such cases, with close attention to the advancing head of the column, since many protrusions are concealed once the opaque medium covers them. In his opinion, one of the advantages of Pantopaque was that it was not so opaque as to obscure fine gradations of density.

Followup studies with Pantopaque sometimes revealed previously overlooked lesions. At DeWitt General Hospital, when men who had had unilateral disk surgery without relief were reexamined, another ruptured disk was sometimes found at a higher level on the same side, or one or more disks were found on the other side (*35*).

Myelography also revealed other lesions. At Thayer General Hospital, it demonstrated congenital absence of the odontoid process of the second

cervical vertebra associated with a dislocation of the first cervical vertebra onto the defective second. At Thomas M. England General Hospital, 1st Lt. Edwin C. Ernst, Jr., MC, and Major Heilbrun demonstrated intraspinal hemangiomas by this method.

Rheumatoid spondylitis.—Spondylolisthesis was a relatively frequent roentgenologic finding in general hospitals, and several special studies were made of it. At Hoff General Hospital, Maj. Edward W. Boland, MC, and Major Present (*36*) analyzed 100 cases with special reference to diagnostic criteria. The diagnosis, they pointed out, was not to be made without radiologic evidence of sacroiliac involvement unless characteristic changes were present in apophyseal joints, changes which might not occur until 3 years had passed.

An important diagnostic study of spondylolisthesis was made at Nichols General Hospital by the chief of the radiology service, Lt. Col. Harold O. Brown, MC.

SOFT-TISSUE OSSIFICATIONS AND BONE EROSIONS IN PARAPLEGICS

Among the numerous complications to which the paraplegic casualties hospitalized in neurosurgical centers were subject was neurogenic ossifying fibromyopathy; that is, para-articular ossifications. Most of these patients had sustained combat or other traumatic injuries to the spinal cord or cauda equina. Among the studies made of these ossifications were the following:

1. At Halloran General Hospital, Colonel Soule (*37*) reported on 23 such ossifications (fig. 52), observed in 62 paraplegics, in one instance secondary to an epidural abscess in the lower thoracic spine and in another to nontraumatic spinal cord disease of an unknown nature.

These deposits were chiefly about the hips and knees. The deposits about the hips were extracapsular and most extensive about the margins of the capsules. When they were well developed, they partially ensheathed the hips and produced ankylosis. The deposits about the knees were most prominent in the region of the medial collateral ligament, but they frequently extended upward over the arch of the medial condyle to become attached to the distal shaft of the femur. Occasionally, deposits lateral to the knee were observed.

No relation could be traced between the presence of these deposits and the severity of the injuries, the site of the neurologic lesions, the timelag in surgical treatment, the presence or absence of decubitus ulcers, the presence or absence of urinary tract infection or other infections, the presence or absence of associated injuries, the ages of the patients, or the blood calcium and total protein levels.

Only 3 of the 23 patients showed any clinical evidence of improvement in their paraplegia, and in 1 out of 3 there was no improvement in the extremity showing ossification.

FIGURE 52.—Ossifications in paraplegic patients, Halloran General Hospital, Staten Island, N.Y. A. Heavy masses of ectopic bone about both hips. B. New bone about distal femurs.

2. At Ashford General Hospital, Maj. William C. Ward, MC (*38*), reported para-articular ossifications about the hips or knees, or about both joints, in 4 of 88 patients observed. One patient had a decubitus ulcer over the greater trochanter. In this case, extensive ossification involved the hip joint capsule, especially laterally, and there was also extensive calcification about the medial and lateral aspects of both distal femurs and the medial aspect of the left knee. In all the cases studied, the ossifications produced varying degrees of ankylosis and fixation of the extremities, and militated against satisfactory rehabilitation.

3. At Thomas M. England General Hospital, Colonel Heilbrun and Capt. William G. Kuhn, Jr., MC (*39*), found 43 patients with deposits of ectopic

bone, chiefly about the hips and knees, in 99 paraplegics. In most instances, the ossifications appeared as solitary or multiple bony nodules in the capsule or outside of it, but in a few cases, bone formation was so massive that it completely ensheathed the joint and rendered it immobile.

Erosions were noted in 45 of the 99 paraplegics treated at Thomas M. England General Hospital (*39*), chiefly in the lateral aspects of the greater trochanters. No reactive changes could be identified in the underlying bone, but as time passed, there appeared to be a reshaping of the bones, and some new bone proliferation became evident about the peripheral portions of the eroded areas. They were most evident in patients with decubitus ulcers, particularly those of long duration. In the cases in which both changes were present, there was no obvious relation between the erosive lesions and the soft-tissue ossifications.

An instance of calcification not related to trauma was the massive calcification of the liver, apparently on the basis of alveolar hydatid disease, reported by Major Heilbrun and Capt. Andrew J. Klein, MC, at Thomas M. England General Hospital (*40*). Diffuse calcification of the pancreas was also observed (*41*).

OSSIFICATIONS SECONDARY TO TRAUMA

Major Soule, at Halloran General Hospital (*42*), reported that ossification of the coracoclavicular ligament is a common sequela of trauma to the ligament sustained in association with acromioclavicular dislocation. He compared it to the ossification of hematomas in muscles such as the quadriceps femoris, brachialis anticus, and rectus abdominis, or in the ligaments about the knee, elbow, and ankle.

Of 18 patients with acromioclavicular dislocations, 14 subsequently developed ossifications in the coracoclavicular ligament. The process appeared as early as 22 days after injury, in the form of a cloudlike density which, over a period of 6 to 8 weeks, assumed the characteristics of dense, trabeculated bone. If ossification did not appear within 6 weeks after injury, it was not noted in later examinations. It did not seem to contribute to the patient's disability; in fact, it might actually aid in stabilizing the joint.

Similar ossifications were observed in other soft tissues of the extremities (*43*).

INJURIES AND ANOMALIES OF THE BONES

The heavy orthopedic workload in all general hospitals in the Zone of Interior has already been commented on several times. Shattering comminuted fractures, caused by high explosives and penetrating missiles, were observed in great numbers and in all locations. Infection, going on to osteomyelitis, was not infrequent until the introduction of penicillin. Then infec-

tions came under control, and the clinical improvement was closely paralleled by radiologic improvement.

Reconstructive surgery was greatly expanded with the advent of penicillin. Radiographs showed many remarkably successful results, including cases in which bone grafts were used.

The largest series of march fractures were reported from regional hospitals at camps throughout the country; these patients did not, as a rule, reach general hospitals.[5] Lt. Col. Glenn D. Carlson, MC, and Capt. (later Maj.) Royal F. Wertz, MC (*44*), reported 69 cases from Brooke General Hospital, 66 involving the metatarsals, 2 the distal femur, and 1 the mid portion of the body of the femur. In no instance did these—or any other—observers note any correlation between these injuries and the previous civilian occupations, the bony anatomy of the feet, or the bony metabolism as indicated by studies of serum phosphorus, serum calcium, phosphatase, and cevitamic acid. Almost all the fractures occurred in recent recruits, under basic training, especially those on the march and carrying heavy equipment.

Diagnosis depended upon technically perfect roentgenograms. Less than half of the films showed definite fracture lines, and the commonest finding was dense subperiosteal callus.

Among the interesting and unusual cases reported were the solitary cysts of the calcaneus observed in three young adult soldiers by Colonel Copleman, Maj. Marino F. Vidoli, MC, and Maj. (later Lt. Col.) Francis J. Crimmings, MC, at Lovell General Hospital (*45*). Only nine other cases were reported in the literature. It was theorized that these cysts might have originated as localized dysplacic processes resulting from multiple minor traumas. Maj. Samuel H. Nickerson, MC (*46*), described several instances of maldevelopment of the patella and the quadriceps extensor apparatus, apparently on the basis of genes which possessed abnormal mesodermal and ectodermal characteristics.

Probably the first use of the Küntscher nail observed in the United States was at Thomas M. England General Hospital, in a German prisoner of war with a transverse fracture of the mid femur. He had been cared for by a German orthopedic surgeon, and he said that he was ambulatory in 5 days. Roentgenologic examination at the U.S. hospital showed beginning healing of the fracture, as evidenced by callus. Alinement was excellent, and recovery was without incident. When healing was solid, Lt. Col. Rafe N. Hatt, MC, removed the intramedullary prosthesis, after some effort. It was a hollow metal triangle, with an incomplete base, shaped to allow for the general curve of the femur.

There was an interesting corollary to this case. It aroused a great deal of medical comment, which reached the lay press, including *Time Magazine*, in which it was written up. An Army medical officer in Germany had run

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[5] The clinical and other aspects of march fractures are discussed in detail in the volume of this series dealing with orthopedic surgery in the Zone of Interior, now in preparation.

across a handbook of the German Medical Department in which the technique of internal intramedullary fixation was described for every long bone in the body. When he read the article in *Time*, he sent the handbook to Colonel Hatt. Intramedullar nailing has become, since the war, a commonly used technique in the United States, proving, once again, that medical knowledge has no national borders.

CARDIOVASCULAR CONDITIONS

Special techniques for cardiovascular conditions were introduced at Walter Reed General Hospital in 1943 and later at other named general hospitals. Visualization of the cardiac chambers and intrathoracic blood vessels by contrast media (cardio-angiography) was of great value in the differentiation of mediastinal neoplasms from aneurysms of the heart, pulmonary artery, and aorta, as well as in the accurate diagnosis of various types of congenital heart disease.

The heart was often examined with barium in the esophagus to demonstrate possible enlargement of the left atrium and aortic anomalies which might produce displacement of, or pressure on, the barium-filled esophagus. Straight lateral projections were most useful, but posteroanterior films were also made.

Phlebography with contrast media was of great value in the diagnosis of subclinical thrombosis of the peripheral veins, a condition which, if properly diagnosed in time for preventive measures to be used, reduces the frequency of pulmonary embolism.

The history of one radiologist is of interest in this connection. When he was setting up the X-ray department of an oversea hospital, he had a chest film made of himself, in order to test his machine. To his surprise and horror, the film showed what appeared to be multiple nodular metastatic lesions of the golf-ball type. He was returned to Walter Reed General Hospital, with the prognosis that death was only a matter of time. The young officer, however, in spite of the diagnosis and prognosis, continued to be remarkably healthy. Colonel Hampton studied the films intensively for several days and finally observed that, between the first film made overseas and the films made at Walter Reed General Hospital, there was a slight decrease in the size of the nodules. Further study of the oblique and other special exposures showed that all the lesions were at the common locations of pulmonary infarcts. Colonel Hampton therefore changed the diagnosis from metastatic malignancy to multiple healing pulmonary infarcts. When the patient was questioned, he recollected that a few days before he tested his X-ray machine, he had gone on a long hike and, at the end, had noticed some pain in his legs, which he disregarded but which obviously explained the multiple emboli shown on the film. Serial films showed progressive healing, and he was returned to full duty.

Arteriovenous fistulas were the not infrequent result of vascular injuries from high explosive shell fragments and other missiles. Colonel Pendergrass reported 32 such lesions from Ashford General Hospital, many of them associated with cardiac enlargement and congestion of the pulmonary vessels (*47*). Both of these abnormalities disappeared after surgical elimination of the fistula. The cardiac enlargement was frequently not apparent when commonly accepted standards were applied but became evident when preoperative and postoperative roentgenograms were studied comparatively. No appreciable changes occurred in the size of the heart when the fistula was occluded, but the heart rate slowed and the amplitude of contractions increased. After operation, most patients showed transitory increases in the cardiac size. Then the diameter began to decrease, and within periods varying from 14 days to 6 months after operation, some 84 percent of the patients showed an average decrease of 1.18 centimeters.

Major Scribner, head of the radiologic service at DeWitt General Hospital, observed a number of arteriovenous fistulas (figs. 53, 54, and 55). One of the most interesting, the result of a gunshot wound, was between the abdominal aorta and the inferior vena cava. The patient made an uneventful recovery after its surgical extirpation. It was believed that this was the second successful case of the kind.

Major Copleman reported from Lovell General Hospital a case in which an anomalous right subclavian artery arose from the arch of the aorta distal to the left subclavian artery and passed obliquely behind the esophagus (*48*). The chief clinical symptom was substernal pain, without dysphagia. The roentgenologic appearance was that of an oblique pressure defect on the upper esophagus, somewhat similar to that produced by a right aortic arch. The lesion frequently produces dysphagia.

NEOPLASMS

Since most patients in military hospitals were young male adults, the neoplasms observed were chiefly those to be expected in this age group. The experience at Hoff General Hospital was typical. Major Present (*49*) reported that, in the first 3,045 admissions, 45 patients were found to have neoplasms, 17 of which were malignant and 28 benign. The malignant tumors included 4 adenocarcinomas of the rectum and sigmoid colon; 1 carcinoma of the pancreas; 4 carcinomas of the lip; 2 carcinomas of the skin; 2 gliomas of the brain; 1 sarcoma of the tibia and 1 of the mandible; 1 seminoma of the testis; and 1 melanoma of the eye. The benign tumors included 7 lipomas, 5 osteochondromas, 3 adenomas of the thyroid, and a scattering of other tumors. Three of the benign tumors, a fibroma of the stomach and a dermoid cyst and a teratoma of the mediastinum, were unusual enough to be reported.

At Percy Jones General Hospital, Colonel Heublein and his associates found 24 malignant tumors in 30,442 admissions (*50*). Of the 24 tumors,

FIGURE 53.—Arteriograms made at DeWitt General Hospital, Auburn, Calif. A. Aneurysm of femoral artery, with dilatation of femoral vein. Shell fragment responsible for injury lies medial to aneurysm. B. Arteriovenous fistula of lower leg. C. Large saccular aneurysm of upper posterior leg.

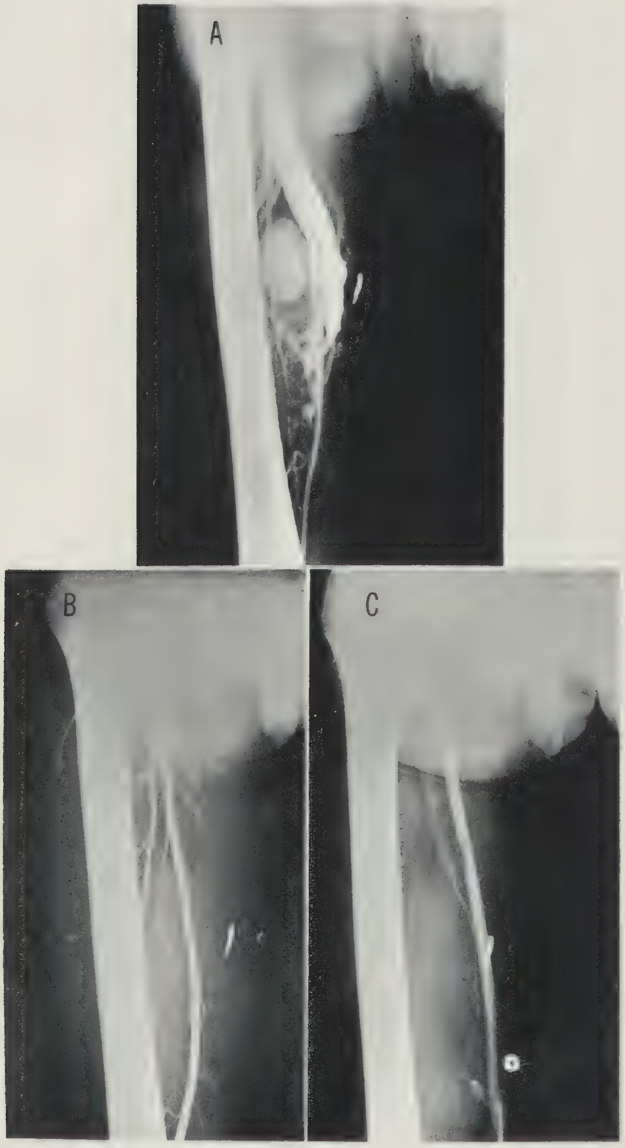

FIGURE 54.—Serial studies of arteriovenous fistula between right femoral artery and vein. A. Preoperative arteriogram after injection of right femoral artery, showing fistula and shell fragment responsible for injury lying medial to fistula and aneurysm. Medial, most greatly dilated vessel is femoral vein; massive dilation is result of arterial pressure. B. Arteriogram 5 months after repair of arteriovenous fistula. Injected right femoral artery now appears normal. Shell fragment is still in situ. C. Venogram 5 months after repair of arteriovenous fistula, after injection of dye into veins of lower leg. Right femoral vein appears normal. Shell fragment is still in situ.

FIGURE 55.—Venogram made after injection of lower tibial vein, showing obstruction of deep venous system. Dye outlines only superficial veins.

10 were Ewing's sarcomas, an incidence explained by the fact that the hospital was both an amputation center and a center for deep X-ray therapy. The experience there indicated the importance of frequent X-ray observations of patients with symptoms in any way suggestive of this condition. Soldiers in the second and third decades of life, with small lytic lesions and slight periosteal reactions associated with tumors of the soft parts, should be regarded with particular concern. Judiciously applied deep X-ray therapy was found to be a useful adjunct to surgical treatment.

Another unusual malignant neoplasm was the neurogenic sarcoma of the jejunum associated with von Recklinghausen's disease observed at Lawson General Hospital (*51*).

Teratomas of the testis, Hodgkin's disease, leukemia, and other types of lymphoma were also observed at general hospitals, as would be expected in

view of the young age group treated. They are described in the chapter on radiotherapy (p. 195).

OTHER STUDIES

A classical study on the roentgenologic appearance of the hypophyseal fossa in health and disease was made by Colonel Heublein at Percy Jones General Hospital (*52*). The average anteroposterior diameter of the fossa was 10.66 and the depth 8.30 mm.; the smallest measurements observed were 8 by 5 mm. The commoner normal variants were described in the text and by line drawings. The effects on the sella of expanding intrasellar adenomas were present in some detail. It was emphasized that choked disks were seldom seen with pituitary adenomas; the important findings was a primary optic atrophy.

At Letterman General Hospital, Captain Imler (*53*) analyzed the data available on reticuloendothelioses and concluded that they were insufficient to warrant the separation of Hand-Schüller-Christian disease, Letterer-Siwe disease, or eosinophilic granulomas into specific disease entities, or to support the claim of a lipoid metabolic disorder as the primary causative factor. In his opinion, all these diseases were variants of a hyperplastic reaction of the reticuloendothelial system. Lesions involving the bones, the pituitary, and the lungs responded satisfactorily to relatively small doses of irradiation.

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CHAPTER VII

Station and Regional Hospitals in the Zone of Interior

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The history of radiology in station and regional hospitals in the Zone of Interior in World War II is rather simply told. Station hospitals provided the type of service, including radiologic service, provided in the usual civilian hospital. Regional hospitals, to which patients were transferred as necessary from station hospitals, were staffed and equipped to care for patients who required types of treatment not available in station hospitals and also to serve, in effect, as general hospitals for Zone of Interior patients. General hospitals in the Zone of Interior, in contrast, were set up to receive and treat casualties evacuated from overseas as well as Zone of Interior patients who required specialized types of care not available at regional hospitals.

Regional hospitals were first set up in April 1944. At the peak, in June 1945, there were 62, many of which had been converted from former station hospitals (*1*).

STATION HOSPITALS

Size

Station hospitals varied in bed capacity from a low of 50 beds, as at the Army Air Field, Birmingham, Ala., to a high of more than 3,000, as at the Camp Butner Station Hospital in late 1944 (*1*). At this time, the troop strength at Camp Butner varied from 30,000 to 34,000, and the hospital bed capacity was 3,200. When Col. Byrl R. Kirklin, MC, inspected the radiologic service in December 1944, he found that there had been 3,696 X-ray examinations in November and that the average number for each of the preceding 6 months had been 4,000. At the Camp Wheeler Station Hospital, Macon, Ga., which was inspected at the same time, the bed capacity was 1,200; 2,195 examinations had been made in November. The films used per examination in the station hospitals that kept records of these data—reports were not officially required—varied from 1.5, which was regarded as conservative, to 2.2, which was considered high.

Organization

As in general hospitals in the Zone of Interior, the radiologic service sometimes operated under the surgical service and sometimes as an independent service. The latter plan was the more desirable, as it gave the radiologist more freedom of action, though even when the service was a subsection of the surgical service, he was usually allowed to organize the service as he wished within the limits of existing regulations and directives.

When station hospitals first began to function, there was no consultant in radiology in the Office of The Surgeon General. How useful such an officer could be was not fully realized until Colonel Kirklin was appointed to this position in May 1943 (p. 13). His advice was very helpful on his tours of inspection, and his visits were anticipated with pleasure. He was always available for consultation by letter or telephone, even when he was not on duty in the Office of The Surgeon General. After his appointment, there was a general improvement in the X-ray services in all station hospitals, one reason being that they were all conducted according to a uniform plan. Indeed, it is not too much to say that the service they rendered was comparable to the services offered in the best civilian hospitals in the country.

The keeping of adequate records, which was an important function of station hospitals, included the preservation and storage of films. Each hospital devised its own special system, and most systems were approved as efficient when the hospitals were inspected.

Personnel and Training

Medical officers.—The shortage of qualified radiologists (p. 24) was felt in station hospitals as in all medical installations. The qualifications of the radiologists in charge were also highly uneven, varying from certification in both diagnosis and therapy to little more than the course at the Army School of Roentgenology (p. 30) combined with some practical experience in the Army. This was not sufficient training for an officer in charge of a department making more than 2,000 examinations a month. Moreover, a single radiologist could not handle the load of a large station hospital without assistants, and those assigned to him often had no experience at all when they assumed their duties. On the other hand, these new officers, usually with no previous military training, and often with no radiologic experience in civilian practice, showed a remarkable amount of adaptability and became very useful. Some of them, who had been in general practice, had used small X-ray machines in their private offices. Some of them were assigned merely because they had expressed an interest in radiology. A considerable number of these officers maintained their interest after the war. They, along with a number of other previously untrained officers, secured residency training and a number of them became fully qualified in this field.

One reason for the initial shortages of qualified radiologists was that Board-certified civilians were unwilling to enter service as first lieutenants. The situation was improved later when certified radiologists were offered majorities. It was further improved when trainees at the Army School of Roentgenology became available for assignment.

Technicians.—Technicians were necessary in large numbers and were also in short supply. A busy station hospital might need from 12 to 20. The original cadre for a station hospital was usually one trained technician, and sometimes one partially trained technician. The schools for technicians at named general hospitals (p. 40) were not in operation when the need for technicians in station hospitals first arose, and it was necessary for the radiologist to train his own men, formally or informally. Again, it was surprising how quickly enlisted men, with no previous knowledge of radiology and often with limited educational qualifications, became competent technicians.

After the Camp Butner X-ray department had received an unexpected windfall, it found itself with adequate classroom space and with facilities for adequate on-the-job training of technicians. Permission was therefore requested from the hospital commander to establish a school for instruction of X-ray technicians.

The permission was promptly granted, and the success of the school was augmented by the agreement with Brig. Gen. Roy C. Heflebower, Commanding General, Medical Replacement Training Center, for the transfer to it of selected students who had completed basic training at the station hospital to be trained as X-ray technicians. When these trainees completed the course, they were made available to Corps Area Command for replacement.

An X-ray training manual, including the rudiments of X-ray anatomy, was prepared in the department, and each student received a mimeographed copy. Since the school was a local activity and not a War Department function, recognition at the end of the course consisted of a certificate of proficiency issued by the hospital commander.

Practically all station hospital radiologists, as has already been pointed out, necessarily conducted some form of training for technicians. Some training included only practical work, some only didactic lectures, and some both varieties, but, so far as is known, Camp Butner was the only station hospital to set up a school for technicians.

In station hospitals, as in other hospitals, it was often hard to retain qualified men. They were transferred out of the section because they were needed in induction centers and in units preparing to go overseas.

The radiologist in one station hospital, who received monthly calls for at least two technicians from Corps Area Command, was somewhat bewildered, since no technicians were being assigned to the service. Investigation revealed that the hospital morning reports were at fault: As soon as two basics were assigned to the service, to replace the technicians transferred,

the sergeant major promptly changed their specification numbers from Basic 231 to Technician 264, and the department always showed, on paper, an abundance of trained technicians.

Long before the war ended, the technical work of all X-ray departments, as well as the clerical work, was greatly facilitated by the employment of civilian personnel. The technicians thus employed were qualified, sometimes very well qualified, and, since they worked under Civil Service, they had a certain degree of permanency. They were of material assistance in training enlisted personnel.

Development

The development of the Station Hospital at Camp Barkeley, Tex., was unfortunately typical of the development of many station hospitals in the Zone of Interior. These hospitals, it should be remembered, had the mission of providing for troops on the post the sort of hospital service a civilian community would require. This meant that they must provide radiologic service from the time the troops arrived, which was not always a simple matter for medical care that cannot be furnished without a certain amount of equipment.

When the 45th Infantry Division was mobilized and sent to Camp Barkeley for training early in 1941, the station hospital consisted of a few wooden huts, a few pyramidal tents, and some wooden stakes marking the sites of hospital buildings to be erected. At this time the primary mission of the station hospital was the support of the troops of the 45th Division. Its support was a camp function, however, and the hospital was therefore under the overall command of the commanding officer of the camp. Before the hospital was in complete operation, the camp also became a Medical Replacement Training Center, and the hospital had to take on other duties.

In the beginning, because nothing but primitive hospital facilities existed, patients requiring surgery were cared for at nearby community hospitals, and most of them received necessary X-ray study in them. Patients with medical conditions, however, who were not critically ill were admitted to the hospital facilities that existed. This made the establishment of an X-ray service mandatory, and the need was quickly met by the installation of a single field unit in one of the two rooms designated for the X-ray department in the still unfinished surgical building.

Facilities

Facilities varied from hospital to hospital. They were usually more satisfactory when the radiologist to be in charge of the service was experienced in this field and when he was assigned before the department was in operation. He was then able to offer advice, which was usually accepted, on its arrangement. At Camp Barkeley, two officers from the Office of The Surgeon General, there for another purpose (p. 191), had instructions to authorize

whatever was necessary for an efficient department, a permission of which the radiologist took the fullest advantage. He requested a W–1 building for the service, together with authority to remodel the existing facilities, air condition the darkroom, and requisition all the equipment necessary for a modern X-ray department.

When Colonel Kirklin inspected Camp Butner Station Hospital, Durham, N.C., in December 1944, he observed that "this fine hospital would lend itself admirably for a named general hospital," and that the X-ray Department, with some rearrangement of the darkroom, which was a little small, would have sufficient space and equipment for such a hospital. The Camp Butner Station Hospital became a named general hospital some 6 weeks later.

Equipment

When many station hospitals began to operate, X-ray equipment and supplies were entirely lacking or extremely inadequate. Shortages were the general rule in the hospitals that opened in 1941 and 1942. By 1943, the situation was greatly improved. When the Camp Barkeley Station Hospital X-ray department began to operate, its equipment consisted of one field unit with a single X-ray tube (spare tubes were not provided, nor were requisitions for them honored); one small 5-gallon developing unit, without refrigeration; eight assorted cassettes and screens; one dozen assorted film hangers; and one 14- by 17-inch illuminator, without bulbs.

Lacking were all the other essentials of an X-ray department, including a refrigerating unit, X-ray tables, lead film markers and numbers, lead protective aprons, sheet lead or leaded rubber, film cutters, filing envelopes, request forms, report forms, technical manuals, tungar bulbs for view boxes, view boxes, hanger racks; office furniture of all kinds, developing tanks of adequate size, grids; spot-film devices, and X-ray equipment of adequate capacity. Added to these major handicaps was the totally inadequate space provided for X-ray operations.

It is easy to understand the hospital commander who said to a radiologist reporting for duty, "I am not as much concerned about your ability as a radiologist as I am about your ability to improvise." Until the supply situation improved, improvisation was the key to operation of all departments.

At the Camp Barkeley Station Hospital the first need was for lead markers to identify films. Crude numbers and letters were made out of malleable wire with the help of needle nose pliers and wire cutters.

Although much of the X-ray work involved chest X-rays, no upright cassette holders were available. With the aid of the hospital carpenter, 2- by 4-inch studs were nailed to the wall, with an adjustable crossbar to hold the cassette. There were a number of variants on this design, one of the more refined including suspension of the crossbar with window sash weights, to enable the technician to adjust the cassette to the height of the patient.

For drying racks, wires were strung overhead across the X-ray room and the films were hung by paper clips, as soon as they were processed, on the few hangers provided. Tanks for washing the films were constructed of sheet metal.

Most of the stationary X-ray units finally provided for station hospitals were single-tube tables, with fluoroscopes and Bucky-Potter diaphragms. No grids were available, and their lack made fluoroscopy difficult, especially on large patients. A number of radiologists overcame this shortage by purchasing grids with their own money.

Because of the shortages of all kinds of supplies in the early days of station hospitals, the various chiefs of service watched the supply shelves carefully and appropriated any items their services might find useful, whether they were in the proper category numbers or not. Some odd consequences followed. At one large station hospital, the supply section received a gross of 200-w. blue tungar bulbs for X-ray illuminators. The chief of the dental service was the first to discover them, and, since he had several dental clinics without bulbs in his overhead dental chair lights, he promptly requisitioned the entire supply. When they were installed, however, they were installed vertically, with the base up, and, since they were intended to operate only in the horizontal position, they all blew out and were lost to both radiologist and dentist.

Maintenance

Before a maintenance service was provided in the Zone of Interior (p. 137) servicing of equipment proved a considerable problem, which was further complicated by the fact that the majority of large station hospitals were in relatively remote areas and the firms which could furnish the service were located in the larger cities. Some departments were fortunate enough to have technicians who could handle most repairs. Civilian companies were most cooperative whenever they were available. Authorization for calling servicemen could not always be obtained, however, because no funds were ordinarily provided for this purpose, and special mention should be made of the number of civilian servicemen who contributed their services without charge. In any future conflict, service personnel should be identified and concentrated in corps or other areas, from which they could circulate on routine tours of inspection of equipment or in response to special calls.

Workload

As has already been pointed out (p. 185), most station hospitals carried heavy workloads. There were also special problems, most of which might have been avoided if there had been more specific control from the Office of The Surgeon General, in which, as noted earlier (p. 13), a part-time consultant was not appointed until May 1943.

Chest examinations.—An incident at Camp Barkeley illustrates one such problem: On 15 September 1941, five trainloads of enlisted men, 6,500 in all, arrived from the Louisiana Maneuver Area, to be processed for discharge on the basis of having completed the required year of service. The commanding officer of the camp called on the station hospital for 6,500 chest X-rays, to be taken at once, so that their discharge could be completed. When he was advised that the maximum number of examinations in any single day would not exceed 500, he reiterated that 6,500 men were due out of the Army at once and they could not be discharged without chest X-rays.

Since the impasse could not be settled locally, the corps area surgeon was called, and he added to the confusion by stating that with the facilities available, 200 chest X-rays per day should be the maximum. The dispute was then referred to Washington, and officers were sent to the camp from the Office of the Inspector General and the Office of the Quartermaster General. Meantime, the hospital commander advised the radiologist just to use his best judgment and do the best he could. On this basis, the 6,500 chest X-rays were made in 10 days.

Indirectly, the incident was highly beneficial to the X-ray department. The hospital was to have a peak capacity of 2,800 beds, which would require a correspondingly large X-ray department. The officers sent from Washington had carte blanche in the matter of equipment and supplies, and the department, as already mentioned, took full advantage of the situation and procured whatever was needed for diagnostic radiology, as well as facilities for a training school for technicians.

One of the early directives concerning movement of soldiers overseas was that each man have a chest X-ray immediately before his transfer. When oversea movements began to involve thousands of soldiers, it became evident that the requirement could be met only with a great deal of delay, and the directive was therefore rescinded.

Another directive which caused confusion and actual injustice was to the effect that thoracic calcifications numbering 10 or more, or single calcifications measuring 1 cm. or more in diameter (p. 103), would be considered a disqualification for commissions in officers' candidate schools. When this directive was applied, many enlisted men who had completed all requirements were refused commissions and returned to duty in their original grade. Experienced radiologists, while they necessarily complied with the directive, were almost unanimous in their disapproval of it, and it was eventually rescinded, though only after irrevocable injustices had been done to some enlisted men.

Gastrointestinal examinations.—The workload at station hospitals included an extraordinary number of requests for gastrointestinal examinations; any medical officer in the hospital could initiate the request without consultation with a gastroenterologist or any other screening of the request. In one hospital, in which requests for such examinations averaged 25 a day, the

chief of the medical service issued orders that no neuropsychiatric patient should be discharged without a gastrointestinal study, an order which the single radiologist, with limited equipment and untrained technicians, could not possibly honor. In this hospital, the X-ray service was directly under the hospital commander, and the difficulty was referred to him. After a considerable search, a qualified gastroenterologist, who was serving as cardiologist on the medical service, was located. A subservice for gastroenterology was then set up, and all requests for such examinations were screened through it. As a result, requests fell from 25 per day to 20 a week.

The workload was particularly onerous in hospitals in which inexperienced radiologists were in charge and reading of the films was a slow process. Experienced civilian radiologists in the community were often of great help. The radiologist at Fort Ethan Allen, for instance, near Burlington, Vt., was only 1 year out of Syracuse University Medical School. He was assisted in reading most of his films by the radiologist at nearby Mary Fletcher Hospital, the principal teaching hospital of the University of Vermont College of Medicine. This young officer (1st Lt. Clayton H. Hale, MC) acquired an interest in radiology from his Army experience and after his separation from service he served residencies in radiology at the University of Vermont and Massachusetts General Hospital. A few years later he returned to his alma mater, Syracuse, as Professor of Radiology.

Therapy

There was no provision for X-ray therapy in station hospitals, but it was impractical to hospitalize patients who needed only superficial therapy and transfer them to general hospitals in which it was available. Some radiologists who were qualified in therapy as well as diagnosis therefore borrowed r meters and calibrated the field X-ray units in their departments for the administration of the necessary treatment. These units functioned admirably at 85 kvp. (kilovolt peak) and 4 ma. (milliampere).

REGIONAL HOSPITALS

Size and Workload

The development and function of regional hospitals have already been described (p. 185). They were established with two purposes: (1) to take some of the load off general hospitals, then (April 1944) crowded with returning casualties and to be still more crowded after D-day, and (2) to make better use of the facilities of station hospitals, which were no longer taxed by the requirements of the massive mobilization of 1942 and 1943. Like the station hospitals from which many of them were converted, their X-ray departments sometimes functioned under the surgical section and sometimes independently, under the hospital commander.

The size of regional hospitals and the workload varied widely. To illustrate (all figures, which are derived from Colonel Kirklin's reports, are for November–December 1944):

At Camp Stewart, Savannah, Ga., the troop strength was 8,000, the authorized beds 700, and 1,518 examinations were made, using 1.8 films per examination, in November 1944.

At Fort Jackson, S.C., the troop strength was 25,000–30,000, the authorized beds 1,800 and the total bed capacity 2,591; in November 1944, 2,940 diagnostic X-ray examinations were made, plus 2,280 routine chest examinations, using 1.6 films per examination.

At Fort Bragg, N.C., the troop strength was 40,000, the authorized beds 2,000 and the total bed capacity 3,128; during November, 2,807 examinations were made, using 2.6 films per examination. This hospital had to operate a main section and two subsections, and the arrangement was not conducive to efficiency.

At Fort Benning, Ga., the troop strength was 80,000 and the authorized beds 3,200. During November 1944, 7,428 X-ray examinations were made, plus 2,466 examinations of the chest in the induction center on the post. This hospital also operated a main section and two subsections, and its use of films, 0.9 per examination, was extremely conservative and efficient.[1]

Personnel

A number of hospitals, such as those just mentioned, were obliged to operate their X-ray departments in sections, and the arrangement frequently made for uneconomical use of scarce personnel. Occasionally, the hospital commander was a Board-certified Regular Army radiologist, who had had to be diverted from his specialty to administrative duties. At the Fort Bragg Regional Hospital, Lt. Col. Frederick K. Herpel, MC, who was serving as surgeon of the personnel center on the post, was a Board-certified radiologist, with many years of practice in the specialty in various Army hospitals. He was undoubtedly needed in his present position, but he was a great loss to radiology, particularly in a hospital where, as just noted, the arrangements were such that radiologic personnel were not used economically.

In most regional hospitals, the heads of the radiologic service were Board certified or had sufficient qualifications to secure certification when circumstances permitted. Many of them were qualified in both diagnosis and therapy.

In a few instances, the chiefs of service or other personnel were graduates of European medical schools (Austria, Hungary), who had come to the United States and secured their training and certification at U.S. medical schools. At Camp Blanding, for instance, the assistant radiologist was a graduate of

[1] This statement is derived from Colonel Kirklin's report to The Surgeon General after his inspection of the X-ray service at Fort Benning Regional Hospital on 3 December 1944. The figure represents such unusual economy in the use of films one would be inclined to reject it if it were not for its source.—K. D. A. A.

the University of Vienna School of Medicine; he obtained his training in New York medical schools, was certified in both diagnosis and therapy, and had been in the Army for 4 years, during 2 of which he was an instructor in the Medical Department Enlisted Technicians School at the Army and Navy Hospital in Hot Springs, Ark. The Camp Blanding Hospital had a particular wealth of personnel, for the chief of service was certified and his assistant was eligible for certification.

In his visits to regional hospitals, Colonel Kirklin frequently noted that radiologists had ranks lower than their qualifications warranted.

Large numbers of technicians were necessary to carry the workload in regional hospitals. The department at Fort Jackson had 18, with 4 clerical helpers, while the department at Fort Bragg had 21, with 11 clerks and typists.

The qualifications of the personnel at regional hospitals were reflected in the generally excellent quality of the work done in them. In his inspection tours, Colonel Kirklin occasionally found it necessary to remind the radiologists that certain procedures, such as venography, were to be performed only at special centers in general hospitals. He also always insisted that to avoid medicolegal difficulties, as well as in the interest of efficient work, all radiographic and fluoroscopic work must be done in the X-ray department itself and not by nonradiologically trained personnel on the hospital wards (p. 17).

REFERENCE

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CHAPTER VIII

Radiation Therapy

Milton Friedman, M.D.

Section I. Administrative Considerations

PERSONNEL AND TRAINING

At the end of fiscal year 1945, which was roughly the end of World War II, there were 1,336 radiologists in the Army, not more than a dozen of whom were classified by MOS number (3182) as qualified in radiation therapy only (*1*). Another MOS number (3308) indicated that the officer was qualified in both diagnosis and therapy. The plan of using still another number to indicate that he was qualified only in radiologic diagnosis had not yet been implemented. Meantime, the code R–D–2 was used to indicate qualification in radiologic diagnosis only and the code R–T–2 qualification in radiation therapy only. D–DT–2 indicated qualifications in both fields. MOS designations also ranged from A through D; D indicated that the officer had had experience in radiology or radiation therapy or both, ranging from brief periods up to 2 years. In the code just described, the number 2 equaled the letter B.

The number of qualified radiotherapists in the Medical Corps was small, as just noted, and, in the opinion of at least some observers, some of the officers certified by rating boards did not deserve the certifications they had received. The story of attempts to raise the standards in this specialty, which was an external endeavor, does not properly belong in the history of radiotherapy in World War II beyond the statement that the effort was a continuing one. It might be added that the American Board of Radiology was provided with useful data for its records concerning the capabilities and subsequent careers of radiologists who had been certified by the Board as specialists in radiation therapy.

During the first months after the United States entered World War II, several thousand medical officers were assigned to a pool at Walter Reed General Hospital, Washington, D.C. Sixty-two of these were assigned to the Irradiation (later Radiation) Therapy Section for practical training. A considerable number of them were Board certified, and most of them had had previous training in radiation therapy, though usually the experience was quite limited.

Training at Walter Reed General Hospital, in addition to military indoctrination, consisted of didactic lectures on physics and radiation therapy; the clinical application, under supervision, of X-rays and radium; and attendance at diagnostic X-ray conferences, Tumor Board (p. 208) conferences, and general staff conferences. A few officers who underwent training in radiation therapy at Walter Reed General Hospital were later assigned to the Army School of Radiology (p. 30).

There were two reasons that it was important that only medical officers experienced in radiation therapy be permitted to administer radium and X-ray treatments:

1. Even with superficial therapy, an inexperienced operator could do great harm.

2. By the outbreak of World War II, the radiation therapy of cancer, like its surgical management, had become so complex that, unless the disease was treated with skill far above the average, therapeutic efforts directed toward it could be wasted. To control cancer with X-rays produced by the equipment available to Army hospitals, except the equipment available later in the war at Walter Reed General Hospital, it was often necessary to cause severe skin reactions. The inexperienced radiologist was reluctant to employ doses that would produce such reactions, and his timid efforts were therefore often fruitless, if not actually harmful.

PROVISION FOR RADIATION THERAPY

By the end of World War II, nine general hospitals in the Zone of Interior had been designated as deep X-ray therapy centers (*2*); namely, Percy Jones General Hospital, Battle Creek, Mich., Army and Navy General Hospital, Hot Springs, Ark., Fitzsimons General Hospital, Denver, Colo., William Beaumont General Hospital, El Paso, Tex., Brooke General Hospital, San Antonio, Tex., Bushnell General Hospital, Brigham City, Utah, Letterman General Hospital, San Francisco, Calif., Lawson General Hospital, Atlanta, Ga., and Walter Reed General Hospital. Similar centers were also established at Tripler General Hospital in Hawaii and Gorgas General Hospital in Panama.

Each of the designated hospitals was equipped with a 200-kv. (kilovolt) X-ray therapy machine, and as far as possible radiologists assigned to these hospitals were qualified to administer deep radiation therapy. Equipment for supervoltage therapy was provided at Walter Reed General Hospital in 1943 (p. 199). In February 1944, it was recommended that no additional hospitals be allotted deep X-ray therapy equipment (*2*).

Equipment for superficial (100–140 kv.) X-ray therapy (fig. 56) was authorized for all named general hospitals, but it was not issued unless (1) justification for its provision could be established and (2) there was on the hospital staff a radiologist with a rating of R–T–2 (B) or better, and a dermatologist with a rating of MD–2 (B) or better.

FIGURE 56.—Superficial (140 kv.) X-ray therapy machine (General Electric model KX-10).

All hospitals in the Army Service Forces system were equipped with mobile equipment which could deliver 85- to 100-kv. X-rays and which could be used for superficial radiation therapy after it had been carefully calibrated. This equipment, like the equipment just described, was to be used only by radiologists with a rating of R-T-2 (B) or better (*2*).

The letter from The Surgeon General to the Commanding General, Ninth Service Command, dated 14 February 1944, in which these regulations were laid down, pointed out that radiation therapy is a dangerous form of treatment unless it is supervised and administered by personnel thoroughly trained and qualified (*2*). Since the most dangerous X-rays are those produced with relatively low kilovoltage such as is used in the treatment of skin conditions, it directed that extreme caution be exercised in selecting patients to be treated and that radiation therapy for acne, psoriasis, and dermatoses be discontinued. It also directed that accurate and detailed records be kept, specifying the

diagnosis and the amount and character of radiation administered, and that the record invariably accompany the patient when he was moved.

WALTER REED GENERAL HOSPITAL

Up to the entrance of the United States into World War II, radiation therapy at Walter Reed General Hospital constituted a small and minor activity in the Radiology Section. During the war, the increase in activity was so considerable that a special Radiation Therapy Section of the Surgical Service was created. It was housed in a new building which contained, among other equipment, the first modern, nonexperimental supervoltage (1 million-volt) radiation therapy machine in existence. After the war, the building was further enlarged to accommodate a rotating cobalt bomb, a 2 million-volt resonant transformer X-ray machine, additional radium and other solid isotope sources for interstitial therapy, and physics laboratories. At this time (1965), this hospital is an outstanding center for the treatment of cancer.

Personnel and Training

The original personnel of the Radiation Therapy Section at Walter Reed General Hospital consisted of Maj. (later Lt. Col.) Milton Friedman, MC, who reported for duty on 4 May 1942. He was assisted by two technicians, one a nurse and the other a Waac (later Wac). In the middle of 1944, a second medical officer, Capt. Daniel Fallis, MC, was added to the staff. Captain Fallis was replaced by Capt. Maurice M. Greenfield, MC. In 1944, two additional technicians were assigned to the section, an enlisted man and another Wac. At first, the section used the hospital stenographic pool but, as the workload increased, a secretary was assigned to it. For many months the section treated from 100 to 125 patients a day, but in spite of its small staff it functioned efficiently at all times.

Of the medical and technical personnel assigned to the Radiation Therapy Section, only the chief of the service had had previous training and experience in radiation therapy. The others, however, quickly assimilated the necessary basic knowledge and techniques, and several of them remained in this specialty after the war.

Expansion of Facilities

In May 1942, the facilities of the Radiation Therapy Section, Walter Reed General Hospital, consisted of two rooms at the end of a long corridor, one containing a 200-kv., deep X-ray machine and the other a 120-kv. machine for superficial therapy. A leadlined safe in a small adjacent room contained about 150 mg. of radium.

During the first year after his assignment, Major Friedman supervised all treatments, typed all reports and correspondence, and trained 35 officers

in the hospital pool in radiation therapy. He also initiated many of the investigations reported later in this chapter (p. 212).

Later in 1942, Col. William LeR. Thompson, MC, then Chief, Radiology Section, recommended to Maj. Gen. Shelley U. Marietta, then Commanding General of the hospital, that a separate section of radiation therapy be established for two reasons: (1) The rapidly increasing workload, and (2) the complexity of the activities and facilities necessary for X-ray therapy. Colonel Thompson's recommendation was approved, and the wisdom of the decision was reflected in the subsequent development of the Radiation Therapy Section.

Procurement of equipment.—Late in 1942, Maj. (later Col.) Aubrey O. Hampton, MC, then Chief, Radiology Section, Walter Reed General Hospital, and formerly Director of Radiology, Massachusetts General Hospital, heard of an experimental supervoltage X-ray machine soon to be discarded at Massachusetts Institute of Technology. After investigation, however, it was concluded that a machine constructed for laboratory use could not withstand the rigors of routine clinical use.

Even before this time, a few supervoltage X-ray machines had been used for cancer therapy in civilian hospitals, but they had many defects. They often broke down. They were large and cumbersome. They were immobile, so that the patient had to be positioned either against the machine or against a hole in a wall through which the X-ray beam came from the machine in an adjacent room. Crossfire or other complicated techniques could not be employed. Finally, the results secured with these machines were not encouraging.

Shortly after it had been concluded that the machine at the Massachusetts Institute of Technology would not be practical for clinical use, the General Electric X-Ray Corp. brought out a new type of 1 million-volt resonant transformer generator for industrial purposes. It was a sturdy and efficient machine, which could withstand vigorous use. Although it was large, it was compactly built and could be moved in all directions. Working with the Radiation Therapy Section, Walter Reed General Hospital, Mr. Dale Trout, physicist for the General Electric X-Ray Corp., redesigned this industrial machine for clinical use (fig. 57). On the basis of increasing cancer problems in the Army (p. 210) and the prospect of improved results with the use of a million-volt X-ray machine, General Marietta obtained the approval of The Surgeon General to purchase the machine, at a cost of $35,000.

The new machine required the use of two floors, the upper containing the hoisting mechanism and motor generator set and the lower serving as a treatment room. Since there was no money for new construction at the hospital, the original plan was to house the machine in a large basement area. When, however, Corps of Engineers personnel who were to install it saw what fine apparatus it was, they constructed a new wing to house it (fig. 58) and to provide facilities for treatment with it.

The new wing consisted of nine rooms: Rooms on two levels for the supervoltage machine and treatment rooms, a room for superficial and conventional deep X-ray therapy, a secretary's office and treatment-planning room,

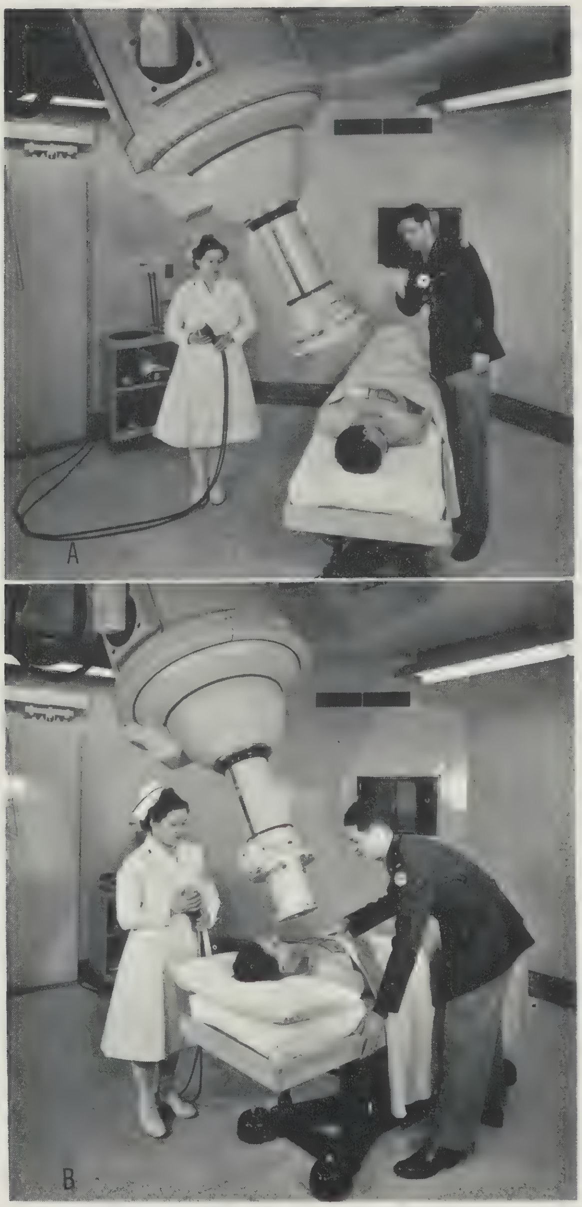


FIGURE 57.—One-million volt X-ray therapy machine, resonant transformer generator. A. Light-beam localizer focused on anterior left chest portal. Movement of machine in all directions is controlled by switch in nurse's hand. B. Double diaphragm system added to nozzle of machine for sharp collimation of X-ray beam.

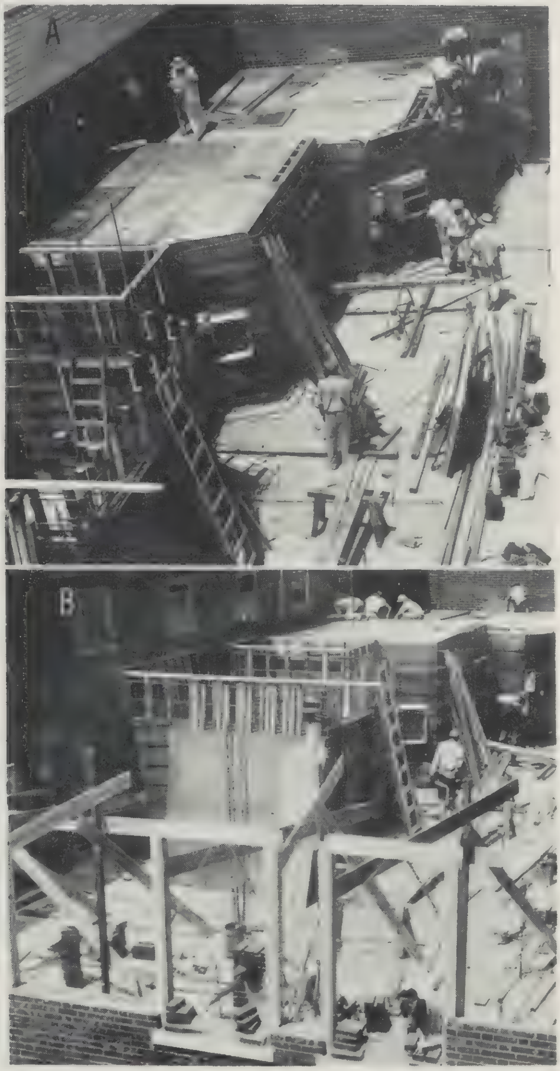


FIGURE 58.—Construction of new wing at Walter Reed General Hospital for Radiation Therapy Section. A. Construction of wooden forms before pouring concrete. The million-volt room, with 18-inch thick walls, is the most distant structure. Frame of viewing window can be seen. Middle room is for 200-kv. machine and nearest room, for superficial radiation therapy. B. Another view of the construction work.

an examining room, a radium room, a waiting room and office, and ancillary rooms. The formal ceremonies, 10 May 1944, at which the new Radiation Therapy Section was dedicated were attended by representatives of military and civilian governmental departments, medical officers from Allied Forces, and physicians from a number of cities on the eastern seaboard.

Malignant Disease

Caseload.—When the United States entered World War II, very few hospitals in the country, and very few radiologists, fully realized the potentials of radiation therapy in cancer. Many of the so-called cancer hospitals were little more than institutions for terminal care, Memorial Hospital in New York, N.Y., and one or two others being almost unique in their progressive, forward-looking methods. Large general hospitals, to which large numbers of cancer patients were admitted, seldom utilized the opportunity for training highly specialized radiation therapists. Instead, it was the custom to rotate residents in radiology periodically through diagnosis and therapy. There was no great interest in radiation therapy, and few published reports even hinted at the potentials of supervoltage irradiation. It would be less than candid, in fact, not to admit that the radiation therapy of cancer in other countries, particularly in France, England, and Scandinavia, was far ahead of that modality in the United States.

The U.S. Army was the only army in the world that treated cancer in its personnel as part of its medical responsibility; in other armies, the cancer patient was treated at civilian centers. Wartime needs of the U.S. Army therefore promptly altered the prewar point of view concerning the radiation therapy of cancer.

As the Army expanded in the period before the United States entered World War II, the radiation therapy caseload increased correspondingly, but the increase was slow. The situation soon altered. In 1941, of 766 patients referred to Walter Reed General Hospital for X-ray or radium therapy, 632 (82.5 percent) had benign lesions and only 134 (17.5 percent), malignant disease (table 3). As the war progressed and the number of patients referred for radiation therapy increased, elective treatment of minor benign lesions was curtailed as a matter of necessity. During the first 10 months of 1945, for example, of 1,298 new admissions to the Radiation Therapy Section of Walter Reed General Hospital, 521 (40 percent) were for the treatment of cancer. It was estimated that, by the end of the war, admissions for malignant tumors increased almost 400 percent, while those for benign lesions increased only 12 percent.

In December 1944, 37 percent of all autopsies performed at Walter Reed General Hospital involved patients with malignant tumors. During the same period, a possible diagnosis of neoplasm was entertained in 33 percent of all histologic examinations of surgical specimens, 9 percent of which showed some form of malignant disease. By this time, the daily census of hospital-

ized patients (excluding outpatients) under treatment with radiation for malignant tumors ranged from 100 to 125. The magnitude of the problem here, which was assumed to indicate the magnitude of the problem for the whole Army, prompted the proposal of an Army Cancer Institute (p. 208).

TABLE 3.—*Yearly distribution of benign and malignant lesions in new admissions, Radiation Therapy Section, Walter Reed General Hospital, 1941–45*

Year	Malignant tumors		Benign lesions		Total
	Number	*Percent*	*Number*	*Percent*	*Number*
1941	134	17.5	632	82.5	766
1942	189	29.7	447	70.3	636
1943	352	34.9	658	65.1	1,010
1944	415	31.4	906	68.6	1,321
1945 [1]	521	40.0	777	60.0	1,298

[1] The figures for 1945 cover only 10 months.

Patients treated in the Radiation Therapy Section of Walter Reed General Hospital were at first derived chiefly from adjacent hospitals located east of the Mississippi River. When supervoltage therapy became available at this hospital, they were referred from hospitals all over the Zone of Interior. As time passed, men with malignant tumors diagnosed overseas were also referred to Walter Reed General Hospital for definitive treatment. Finally, the patients treated here included members of Allied military and civilian missions stationed in Washington and, in a few instances, diplomatic and other personnel.

These Allied military and diplomatic patients occasionally provided opportunities for evaluating cancer therapy in their respective countries of origin, particularly when recurrent lesions had to be treated. As would be expected, therapy at this time was excellent in some countries and archaic in others. Almost all of the patients, curiously, were of high rank. The only foreign cancer patients of low rank were prisoners of war who had been transferred to the Zone of Interior and most of whom received much better medical care there than was available to them at home.

The increasing number of malignant tumors treated by radiation therapy at Walter Reed General Hospital carried another implication not evident statistically: The increase in this type of case greatly increased the workload of the Radiation Therapy Section because patients with cancer required much more attention and had to be hospitalized longer than patients with benign

lesions, a large proportion of whom could be treated on an outpatient basis. The convalescent section of the hospital, later set up at Forest Glen, Md., housed many ambulatory cancer patients who were receiving daily X-ray therapy.

Characteristics of treated cases.—Cancer, generally speaking, is not a frequent disease in the age group which comprised the U.S. Army of World War II. As the Army expanded, however, it became, as just indicated, a numerically serious problem. The predominant types of cancer observed were those which would be expected in a military population between 20 and 40 years of age; almost two-thirds of the treatments were given in this age group. One of the striking increases as the months passed, however, was in cancer of the face in elderly officers and enlisted men, especially those whose duties exposed them to strong sunlight.

The concentration of certain other types of malignant lesions was abnormally high. From 1942 through 1946, for instance, 232 patients with tumors of the testis, and 216 patients with Hodgkin's disease, were treated. For months at a time during this period, one ward had a daily census of 35 to 40 patients with tumors of the testis and another had a similar number of patients with Hodgkin's disease. These unusual concentrations of patients provided unparalleled opportunities to study certain aspects of these two diseases (pp. 221 and 217).

Other tumors observed in relatively large numbers included pituitary adenomas, sarcomas of the bone and soft tissues, malignant lymphomas (lymphosarcoma, reticulum cell sarcoma, and giant follicular lymphoblastoma), carcinoma of the nasopharynx, carcinoma of the cervix, carcinoma of the skin and lip, brain tumors, and other malignant tumors of the head and neck.

It was interesting to note that patients with similar lesions instinctively formed groups for mutual support. The well-known GI sense of humor produced, on occasion, macabre titles for these groups, but the associations also furnished psychologic support, particularly for men with lethal disease. Some soldiers, whose lives had been spent close to the soil in remote rural areas, were inspired to unique solutions for such esoteric medical problems as radiation sickness. One man, for instance, subsisted for a month on 30 raw eggs a day. Another, for the same period, had an almost steady diet of pickles and cucumbers. Both men had tumors of the testis with high gonadotropins. The analogy of these diets to those craved in the gestational state raised the expectation, which never materialized, that some patient might request a diet of chalk.

An incidental observation might be mentioned in this connection, the clinical and numerical disproof provided during the war of the speculation that the circumstances of warfare would increase the incidence of traumatically induced cancer. This speculative increase was not observed.

Untreatable cancer.—In the report of the Surgical Consultants Division, Office of The Surgeon General, for fiscal year 1945, Brig. Gen. Fred W.

Rankin, Chief Surgical Consultant, called attention to the practice of sending patients with inoperable cancer of the rectum and other inoperable malignant tumors to Walter Reed General Hospital or to other centers at which deep X-ray therapy could be administered (*1*). These patients, he pointed out, could not possibly be benefited by this practice. It was cruel to move them far from their homes. They clogged transportation channels. They occupied beds that could be put to better use. And they were simply moved from the hands of surgeons who could do nothing for them to the hands of radiation therapists who also could do nothing for them. General Rankin's recommendation that this practice be stopped at once was adopted. It is only fair to point out, however, that after supervoltage radiation therapy became available at Walter Reed General Hospital, some patients with advanced cancer obtained significant palliation of presumably incurable disease while, with increasing experience, other patients in this group remained well for more than 5 years.

Disposition of patients.—In the early years of the war, patients with cancer which was apparently arrested after treatment would often be returned to full duty. In 1944, for instance, an Army sergeant who had fought on Guadalcanal was referred to Walter Reed General Hospital for treatment of cancer of the tonsil. At the end of 4 months, the tumor was apparently completely eradicated by the deep radiation therapy administered, and he was returned to oversea duty. As cases of this sort multiplied, the impression grew that this was extremely rigorous treatment for good soldiers, and the practice developed of discharging men with cancer, other than cancer of the skin or lip, that had apparently been successfully treated, or at least assigning them to duty in the Zone of Interior.

Unofficial observations of this sort eventually focused attention on the so-called performance status of the soldier whose malignant disease had apparently been eradicated by either surgery or irradiation. The initial elation of the clinicians who had treated him often had to be modified in the light of subsequent evaluation of the total impact of the disease and its treatment on him. The factor of compassion, as just intimated, also entered into the picture. For these reasons, throughout the war years, a progressively larger number of cancer patients were discharged from service even when they were capable of limited duty in the Zone of Interior.

LAWSON GENERAL HOSPITAL

Organization and Facilities

Lawson General Hospital may be cited as an illustration of a named Zone of Interior general hospital in which, without the supervoltage equipment available at Walter Reed General Hospital, excellent deep radiation therapy was carried out.

Usually, when radiation therapy was provided in hospitals already in

existence, compromises had to be made with the ideal and improvisations had to be employed. A relatively ideal situation, however, in which it was possible to plan the X-ray department before the building was constructed, existed at Lawson General Hospital because an experienced radiotherapist, Maj. (later Lt. Col.) John L. Barner, MC, was assigned to it while the buildings were still under construction. The hospital, which eventually was expanded to 3,500 beds, was designated as a center for radiation therapy soon after Major Barner's assignment. The following material is derived from a report which he made, on request of the writer of this chapter, in November 1960:

> The X-Ray Section at Lawson General Hospital was originally operated with two diagnostic machines and a small, inadequate darkroom. It was not long before two additional machines were added, the darkroom was doubled in size, the film-filing room was enlarged, and more space was provided for reading films. Shortly thereafter the radiation therapy section was housed in a wing (known as the BLEB), which was added to one of the original hospital buildings and was constructed to meet the standards of protection laid down by the National Bureau of Standards and the International Roentgen Ray Committee on X-Ray Protection.
>
> Radium was not available at Lawson General Hospital, and Major Barner was not permitted to use his personal supply though he offered to do so. Otherwise, the section was equipped for both superficial and deep radiation therapy. The equipment consisted of a 250-kv. Maximar General Electric machine for deep therapy and a General Electric machine for superficial therapy. Both proved superior in performance and service. Neither required replacement of tubes or valve tubes or any other major repairs during the war; it is understood that both were in use for several years after the war at a local Veterans' Administration hospital before they began to give trouble.
>
> The excellent leadership of Brig. Gen. William L. Sheep, the hospital commander, the cooperation of the radiologists who successively headed the Radiologic Section, and the relatively few changes in section personnel during the war combined to provide an excellent atmosphere for good work. All personnel assigned to the section were above average in both qualifications and performance of duty, and the work benefited accordingly.

Recommendations.—His experience at Lawson General Hospital convinced Major Barner that the efficient operation of a radiation therapy section requires that this section and the section of dermatology be entirely independent of each other. In other words, the dermatologist should have his own superficial radiation therapy or Grenz ray equipment and the radiation therapy section, its own.

Diagnostic and therapeutic radiology should also be completely divorced from each other.

Major Barner questioned the wisdom of providing supervoltage therapy equipment in average general hospitals. It would be better to reserve it, he thought, for the treatment of carefully selected patients in not more than one or two such hospitals. Isotopes (his comment was made in 1960) should be an integral part of radiation therapy. Radium should be available in all general hospitals.

An increase in equipment for deep radiation therapy would require increased personnel, including a physicist and an assistant for the chief radiotherapist.

Caseload

Between May 1941 and March 1946, Major Barner personally gave 27,670 superficial radiation treatments to 1,206 patients and 8,976 deep radiation treatments to 1,057 patients with malignant disease of various types. In addition, between September 1945 and March 1946, when he served as head of the X-Ray Section, he handled several thousand diagnostic interpretations. He made it a practice, from the date of his assignment to the hospital, to keep a carbon of all reports of diagnostic consultations and treatments, and the following figures, which show the numbers of patients and conditions, can therefore be accepted as entirely accurate:

Diagnosis	*Number of patients*
Dermatologic conditions:	
Acne	118
Eczema, generalized	232
Eczema of hands	43
Fungus, feet	122
Fungus, groin	46
Fungus, hands	145
Herpes	11
Lichen, lupus, etc.	49
Pruritus ani	26
Sycosis fungoides	20
Verruca	129
Infectious conditions:	
Blastoactinomycosis	5
Cysts, sinuses, etc.	27
Furunculosis	73
Monilia	3
Otitis media	17
Parotitis	9
Total	1,075
Malignant conditions:	
Basal cell carcinoma of skin	102
Brain tumors (all types)	19
Carcinoma of—	
Bladder	9
Breast	32
Cervix	7
Colon, rectum, and anus	14
Kidney (adenocarcinoma)	3
Larynx	24
Lung	18
Mouth, tongue, etc.	19
Ovary	2
Penis	15
Thyroid	11
Tonsil (squamous and transitional)	16
Uterus	3
Eosinophilic granuloma	5
Ependymoma	9
Fibrosarcoma	1
Hemangioma of bone	10
Hemangioma of skin	31
Hodgkin's disease	97
Hypernephroma	10
Leukemia (lymphomyelogenous)	33
Lymphosarcoma	105
Melanoma	24
Mixed tumors of—	
Palate and carcinoma of palate	11
Parotid	20
Myeloma	6
Osteogenic sarcoma of bone (all types)	50
Peyronie's disease	5
Pituitary tumors (sella, etc.)	13
Polycythemia	3
Sarcoma (general)	48
Squamous cell carcinoma of—	
Lip	62
Skin	27
Teratoma of testis	189
Thymoma	4
Total	1,057
Miscellaneous conditions:	
Arthritides	40
Boeck's sarcoid	3
Bursitis	38
Keloids	35
Sinusitis	12
Syringomyelia	2
Thromboangiitis obliterans	1
Total	131
Grand total	2,263

Section II. Clinical and Research Considerations

BENIGN LESIONS

Before the United States entered World War II, the management of benign lesions by radiation therapy in military hospitals resembled their management in civilian practice. As the war progressed, elective radiation therapy for this type of lesion was limited to keloids, certain bacterial infections, acne, mycotic skin infections, acute dermatoses, and plantar warts and calluses.

Only plantar warts and calluses need special comment. As might have been expected, they became a real military problem. It was simple to eradicate them with doses of 1,500 to 2,500 r (roentgen) given with the superficial radiation therapy machine (100 kv.). The irradiated tissues, however, especially those on weight-bearing parts of the sole of the foot, often could not tolerate the trauma of long marches. It therefore became the practice, in treating these lesions, to shave off more tissue and irradiate less.

In the prewar preparations for radiation therapy, considerable thought was given to its use in gas gangrene. The Army field (Picker) X-ray unit was designed, in part, for giving this type of treatment both prophylactically and therapeutically well forward in combat zones, but improved surgical techniques and the development of antibiotics made its use unnecessary.

ROUTINE OF MANAGEMENT OF MALIGNANT DISEASE

Tumor Board Survey

The routine of management of patients with cancer at Walter Reed General Hospital during World War II provided them, it is believed, with the best possible treatment then available. Each patient was mandatorily reviewed by the Tumor Board, composed of the chiefs of the surgical and laboratory services, the Chief of the Radiation Therapy Section, and the ward officer on the service on which the patient was being treated. The Tumor Board established at this hospital during the war served as the prototype for all Army hospitals. It has continued to function actively and usefully to date (1965).[1] Similar boards now exist in all Army general hospitals and also in

[1] In 1945, at the end of the war, Col. Rettig A. Griswold, MC, Chief of the Surgical Service at Walter Reed General Hospital, and Major Friedman drew up a plan for an Army Cancer Institute to be established at Walter Reed General Hospital. Justification for such an institute was the increase in malignant disease in the Army during the war; the necessity for highly specialized care, both surgical and radiotherapeutic, in cancer; the inadequacy of training in radiation therapy and in the surgery of cancer at this time; the experience of other countries, which showed that cancer is best treated in cancer institutes or in large general hospitals staffed by specialists in its management; the special facilities and ready availability of Walter Reed General Hospital, the National Cancer Institute, and the Carnegie Institute for Terrestrial Magnetism, as well as local hospitals and medical schools; and the practical fact that atomic research had already become a military activity. Specific suggestions were offered for the staffing and equipment of the proposed institute (*3*). The Army Cancer Institute, as such, was never established, but most of the recommendations incorporated in the proposal were adopted at Walter Reed General Hospital and elsewhere.

most civilian institutions in which the management of cancer is considered a special field.

The Tumor Board, whose sessions were attended by the entire hospital staff, met each Tuesday, at 1300 hours. During 1942, when newly inducted medical officers were assigned to the hospital for orientation purposes, they also attended the sessions. On the average, about 300 officers were present each week.

Every patient with cancer was presented in person at a Tumor Board conference, as soon as was practical after his admission. After he had withdrawn, his condition and management were discussed in detail. The vigor and thoroughness of the discussions made the sessions of the Board always instructive and often dramatic.

When the Tumor Board was first constituted, the treatment of cancer in the United States was strongly oriented toward surgery. The Radiation Therapy Section had to fight a continuous uphill battle to maintain its position in the treatment of malignant disease against numerically and vocally strong surgical opposition. The arguments for radiation versus surgery compelled the proponents of each modality to analyze every problem in depth and stimulated them to utilize every possible advantage offered by their respective specialties.

In one case, as an illustration, the discussion concerned a patient with cancer of the skin in the preauricular region. The surgeons who participated in the discussion included, among others, Col. Claude S. Beck, MC; Col. Charles H. Mayo, MC; and Col. Edward D. Churchill, MC. The participants constituted one of the most august assemblages of surgical talent ever focused on a single sick soldier in the history of the U.S. Army. The radiotherapists lost on the formal vote always taken in controversial cases, and surgery was recommended.

The following week the same patient was presented again to the Tumor Board. The result achieved was a beautiful demonstration of tumor excision and plastic repair of the defect with a skin graft. A week later the radiotherapists countered this demonstration by presenting a patient who had had three independent skin cancers of the face treated by irradiation. All the lesions had been so thoroughly destroyed, without leaving scars or defects, that no medical officer present could identify the sites of the original cancers.

The wholesome rivalry induced by these discussions and presentations resulted in superb medical care for all patients. From the standpoint of radiation therapy, the radiotherapist was able to demonstrate the possibilities and accomplishments of radium and X-ray therapy, so that a larger proportion of patients with cancer were treated by irradiation, while new combinations of radiation and surgery were developed for tumors in special locations.

Special Procedures

The workload of the Radiation Therapy Section at Walter Reed General Hospital was very heavy, so heavy that, with the shortage of professional personnel, most treatments had to be given by the technicians, all of whom had only on-the-job training. The therapy, of course, was planned and outlined by the radiotherapist, and many of the treatments were personally supervised by him. As many as 125 treatments were given each day, and 3 to 5 radium treatments were given each week. Treatments with the supervoltage machine were often given in two overlapping shifts, between 0700 and 2000 hours. Incidentally, the use of technicians for the administration of therapy also became common practice during the war in other countries, because of the shortages of trained professional personnel in them.

It became departmental policy, because of the shortages of personnel and the heavy caseload, to treat patients with the same condition one after the other. They were brought to the X-ray section in groups and, following the Army custom, they automatically stood in line while waiting to be treated. The chief of the section, or his assistant after one had been assigned and trained, set the machine in order for the first few treatments of each patient, after which technicians, fully understanding the technique to be employed, took over the responsibility for subsequent treatments.

Shortages of personnel led to other innovations. To insure accuracy of dosage, a number of precision items were devised, including angle guides, light-beam localizers, protractors, and drawing apparatus, all designed to assure a high degree of accuracy in aiming the X-ray beams. Comprehensive graphs and charts showing reactions were prepared for all patients and still (1965) provide useful source data for research purposes.

EFFECTS OF SUPERVOLTAGE RADIATION

Much of the knowledge concerning the effects of supervoltage radiation on normal human tissues, though published after the war, was developed during it and, for that reason, must be included in this chapter (*4–16*). The essential facts are as follows:

When a beam of roentgen rays traverses tissues, the secondary electrons that it produces are stopped by atoms in the cells, with the resulting release of energy. The energy thus released disrupts molecular, chemical, chromosomal, and other biologic activities, with consequent destructions of cells and tissues. The speed of the secondary electrons is related to the voltage employed; if the voltage is very high, the electrons will have such speed that they will travel a considerable distance from the point of impact before they are slowed down to the optimum speed for interaction with atomic units in the cells, particularly in the skin.

Superficial X-ray therapy (100 kv.) produces relatively slow-moving secondary electrons, which are readily absorbed in tissues adjacent to the point

of impact and converted to destructive effect. Only a small amount of radiation (300 r, measured with scattering) is therefore required to produce a skin erythema.

Deep X-ray therapy (200 kv.) produces secondary electrons of greater speed, and a smaller number are stopped in the superficial layers of the skin. A larger amount of radiation (700 r, measured with scattering) is therefore required to produce a skin erythema.

Supervoltage X-ray therapy (1,000 kv.) produces secondary electrons of such tremendous speed that 1,000 r are required to produce a skin erythema.

These facts are of great clinical importance. With higher voltage X-rays, less radiation is absorbed in the superficial layers of the skin, and skin damage is less. A larger amount of radiation can therefore safely be delivered through each skin portal.

The mildness of the skin reactions produced by supervoltage radiation is also of great clinical importance. Current therapy entails the use of such large doses of radiation that, when ordinary deep X-ray therapy is used, severe second-degree, and occasionally third-degree, skin reactions are produced. These reactions are particularly likely to occur in carcinoma of the breast, carcinoma of the upper respiratory tract treated by the Coutard technique, and certain sarcomas. Primary healing may occur, but even if it does, the affected areas may break down and ulcerate months or even years later, and extensive plastic surgery is required for their repair.

When supervoltage radiation therapy is employed, skin reactions seldom exceed first-degree erythema. They cause little discomfort, even during the period of their greatest intensity, and surgical repair is seldom required. This single advantage, in itself, compensates for the increased cost of supervoltage therapy.

Another advantage of supervoltage therapy stems from the behavior of the secondary electrons that it produces. When ordinary high-voltage (200 kv.) therapy is used on deep-seated tumors, such as carcinoma of the cervix, two types of radiation affect the tumor, (1) primary, from the direct beam of roentgen rays, and (2) secondary, that is scattered into the tumor when the primary beam strikes nearby atoms of normal tissue. In deep therapy, when a narrow beam of rays is employed, with a diameter only slightly larger than the tumor itself, there is very little secondary radiation, and the total amount of radiation that reaches the tumor is inefficiently small. The size of the beam must therefore be considerably increased if amounts of secondary radiation are to be produced that can scatter from adjacent normal tissues centripetally to the tumor. Such an increase, however, necessitates irradiation of larger areas of skin and of deeper normal tissues, and the severity of the local and general reactions is increased. Irradiation of a large volume of normal tissue is followed by increased absorption of secondary breakdown products and by severe radiation sickness. In such cases, the eventual radiation that reaches the tumor from a large portal is composed of one-third primary irradiation and two-thirds secondary irradiation, a proportion that

emphasizes the importance of secondary radiation in ordinary high voltage therapy.

When supervoltage therapy is employed, the situation is different. Secondary radiation plays a much smaller role in deep therapy because a larger number of primary rays reach the depths of the tumor. Furthermore, the secondary radiations formed in supervoltage therapy do not scatter haphazardly in all directions but tend to be driven forward toward the tumor because of the tremendous energy of the primary beam. As a result, these radiations are added to, and become part of, the bundle of the primary beam. Narrow beams of X-rays can therefore be employed more efficiently, as can multiple and small beams crossfiring the tumor. For these reasons, twice the amount of radiation can often be delivered to the tumor by supervoltage therapy as compared with the amount that can be delivered by ordinary high-voltage X-rays.

HISTOLOGIC EFFECTS OF RADIATION IN MALIGNANT DISEASE

When the United States entered World War II, not a great deal was known about the histologic changes produced in human cancers by irradiation. Only two investigations, in fact, had been directed to a qualitative and quantitative analysis of these changes, with a view to improving radiation techniques. One of these investigations was conducted by Glucksmann at Cambridge University in England (*17*). The other, begun by Friedman and Hall at the New York University College of Medicine, was continued and expanded at Walter Reed General Hospital during the war (*4*, *8*, *11*, *18*, *19*).

These investigations were based on serial biopsies of human malignant tumors at selected intervals during irradiation; the time at which the biopsy was made was related to the cumulative tumor dose. Basic radiobiologic information concerning the mechanism of the changes induced in tissues by irradiation was thus obtained. The results pointed to avenues for future fundamental investigations and also permitted a number of conclusions of immediate practical value.

These conclusions concerned the following subjects:

1. *The spectrum of dosage requirements for various types of tumors.* Up to World War II, it had been the practice to treat all tumors in each pathologic group with arbitrary, inflexible doses of radiation. All carcinomas of the tonsil, for instance, were treated with a total tumor dose of 6,000 r over a 4-week period. Serial biopsy studies at Walter Reed General Hospital showed that some tonsillar carcinomas that were radiosensitive could be destroyed over this period with dosages as low as 4,000 r, while others that were radioresistant could not be destroyed with dosages up to 7,000 r.

With this information available for all varieties of carcinoma, the princi-

ple was developed of tailoring techniques of radiation to the special requirements of the tumor in the individual patient.

2. *The practice of serial biopsy during radiation therapy.* It became the routine at Walter Reed General Hospital, in certain accessible tumors such as intraoral carcinoma and carcinoma of the cervix, to perform serial biopsies to secure information that would influence and improve the effects of the treatment being applied.

The first biopsy specimen was taken 7 to 10 days after treatment had been instituted, at which time the cumulative dose was 1,500 to 2,000 r. If examination of the specimen showed some degree of radiation damage in all the tumor cells, it was assumed that the technique being employed in the particular case was appropriate and that the total lethal tumor dose would be in the average range, that is, 6,000 r in a 4-week period.

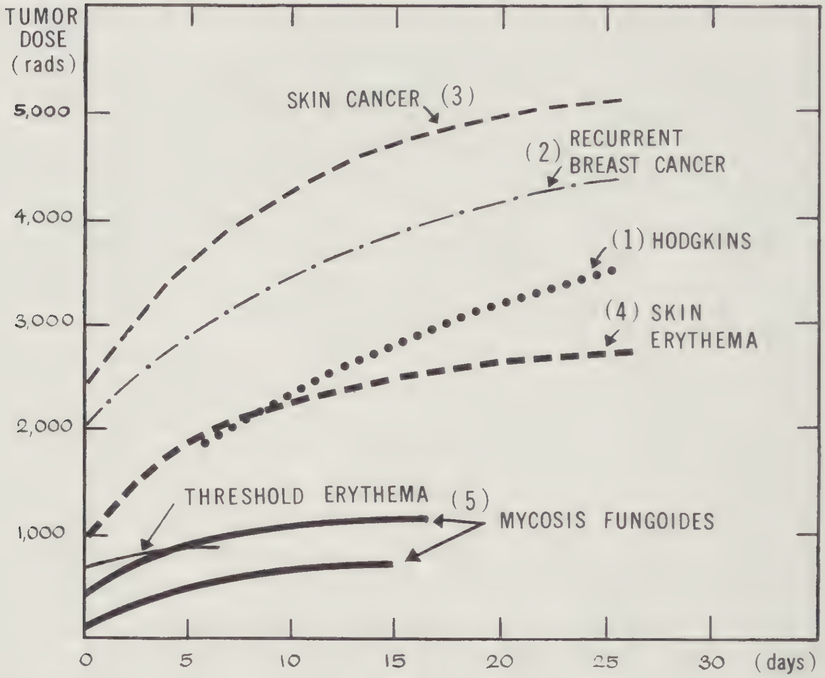
The second biopsy specimen was secured on or shortly after the 21st day of treatment, when about three-quarters of the contemplated tumor dose had been given. If examination of the specimen showed that all the tumor cells had been destroyed, or if only a few cells persisted and they were in an advanced stage of degeneration, it could be assumed that average conditions prevailed and that the plan originally decided on could safely be continued. On the other hand, if any tumor cells, no matter how few, were found at this time to be unaffected by radiation, the principles of radical radiation therapy were invoked and larger-than-average doses of radiation were applied; the possible risk of radiation injury to normal tissues was accepted. Otherwise, these unaffected cells would be likely to account for later recurrence of the tumor.

The principle of radical radiation therapy just described was at first limited to tumors which lent themselves readily to serial biopsy. Later, the plan was extended to growths that did not lend themselves to serial biopsy. In the beginning, the risk of some damage to normal tissues was accepted because of the results it was hoped to achieve. Later, techniques were developed which eliminated this risk, at least to a large degree.

3. *The isoeffect recovery curve.* The radiation treatment of cancer is founded on the principle that after a single dose of radiation, normal cells recover from the effects of the dose somewhat better than tumor cells. This differential recovery rate can be increased by subdividing the total dose into daily treatments that extend over varying periods of time.

Up to 1944, these time intervals were determined empirically. In that year, Strandqvist published a definitive study of carcinoma of the skin in which these intervals had been determined on a carefully calculated basis (*20*). When this communication appeared, similar studies of the isoeffect recovery curve (chart 2) were already under way in the Radiation Therapy Section at Walter Reed General Hospital. When they were completed, they covered Hodgkin's disease, seminoma and trophocarcinoma of the testis, squamous cell carcinoma of the mouth and pharynx, and carcinoma of the breast.

Chart 2.—*Isoeffect recovery curves for various tumors, showing doses, in different time periods, required to destroy tumors or produce erythema*[1]



[1] Curves 3 and 4 are from Strandqvist; curve 5 is from Quimby.

Clinical Considerations

When equipment for supervoltage therapy was supplied at Walter Reed General Hospital late in 1943, initial clinical trials were limited to patients with advanced malignant disease or with radioresistant inoperable tumors. In spite of the greater efficiency of this method, it was not expected that these patients could be cured, and few of them were.

In at least two conditions, however, carcinoma of the esophagus and carcinoma of the bladder, substantial palliative effects were observed. Re-opening of the stenosed esophagus was obtained with greater frequency, and the patency was of longer duration, than with ordinary deep radiation therapy. Even carcinoma of the prostate, which is seldom influenced by deep X-ray therapy, was sometimes benefited by supervoltage radiation.

As the beneficial effects of supervoltage therapy became evident, the indications for its use were cautiously extended to radioresistant lesions and then to radioincurable lesions. Within months, there was no doubt that whatever high-voltage (200 kv.) radiation therapy could achieve, supervoltage (1 million kv.) therapy could surpass.

REACTIONS AND INJURIES

An outstanding clinical observation in the first cases of malignant disease treated with supervoltage X-rays has already been mentioned, the complete absence, or minimal development, of skin erythema, which made it possible to administer much larger doses to each skin field. It had been anticipated that when tumors in the abdominal cavity or pelvis were treated with supervoltage X-rays, the systemic reactions would be similarly mild. They were not. Instead, they were approximately the same as the systemic reactions that occurred after conventional deep X-ray therapy. It was additionally anticipated that normal structures deep within the body could be spared when supervoltage X-ray therapy was employed. The experience with tumors of the testis proved this conclusion unsound also.

In radiation therapy, the skin reaction constitutes a barrier analogous to the sound barrier. Below the million-volt level, skin damage limits the amount of X-rays that can be delivered to a particular area. Above the million-volt level, the almost total absence of skin damage entices the therapist to deliver large doses of X-rays to each area. As a consequence, the deeper structures become subject to injury that usually manifests itself months or years after treatment has been given. To use supervoltage therapy safely, therefore, it became necessary to ascertain the doses that could be tolerated (tolerance dose) by each normal organ (table 4).

TABLE 4.—*Tolerance supervoltage X-ray doses of normal tissues*

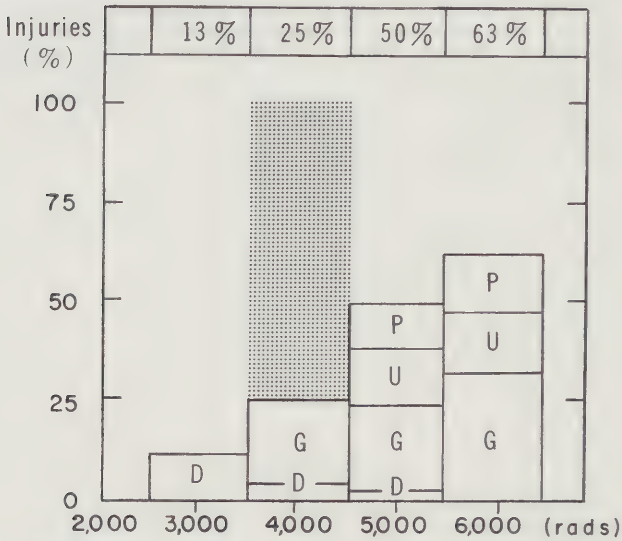
Organ	Tissue dose (rads)	Overall time (weeks)
Central nervous system	5,000	5–9
Stomach	3,500	5–9
Small intestine	4,200	5–9
Transverse colon	4,500	5–9
Rectum	8,000	5–9
Kidneys (part of each)	5,000	5–9
Kidneys (all of both)	2,500	3–6

In short, in conventional deep X-ray therapy, skin tolerance constitutes the barrier to the effective use of radiation therapy. In supervoltage therapy, the tolerance of deep structures constitutes the barrier. To overcome the intolerance of normal structures, it became necessary to devise multiple portal techniques of great precision, and the margin of the X-ray beam had to be sharply defined by means of secondary or satellite lead collimators (fig. 57B).[2]

When radiation injuries of the stomach and intestine began to appear unexpectedly after supervoltage X-ray therapy of retroperitoneal lymph nodes in carcinoma of the testis, a team was organized to study these lesions; the

[2] Further refinements and far better results accompanied the use of the rotation techniques developed after the war.

CHART 3.—*Incidence of injury of stomach in relation to dose of supervoltage radiation therapy* [1]



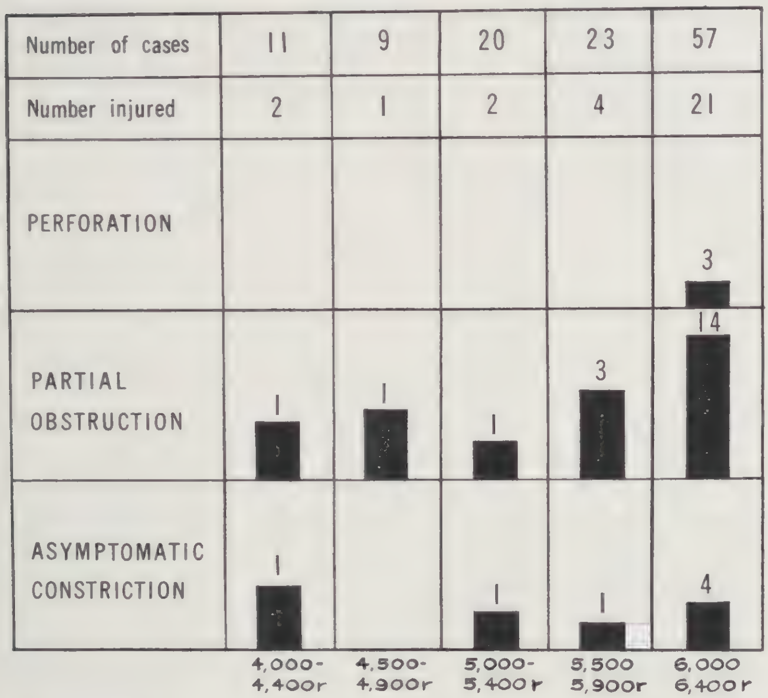
[1] Shaded area designates recommended tumor dose range for routine use, given with the realization that 25 percent of patients receiving it will sustain radiation dyspepsia or gastritis.
Key: D—dyspepsia; G—gastritis; P—perforated ulcer; and U—ulcer without perforation.

study was continued, in an expanded form, after the war. The wartime membership of the team, in addition to Colonel Friedman, Chief, Radiation Therapy Section, consisted of Colonel Hampton, then Chief, Section of Radiology; Colonel Lewis, Chief, Genitourinary Section; Capt. (later Maj.) Irving B. Brick, MC, Department of Medicine; Col. Harold I. Amory, MC, later Chief, Section of Radiology; Lt. William N. Thomas, Jr., MC, USN; Dr. William M. Leavenworth; and Dr. Ralph M. Caulk.[3]

The undesirable effects of supervoltage therapy take various forms, depending upon the areas irradiated. In the mouth and throat, there is prolonged duration of the radiation-induced pseudodiphtheritic membrane, with resulting dysphagia. When the pelvis is heavily irradiated, the reactions may include cystitis, diarrhea, and painful proctitis. These immediate effects are

[3] In 1950, under a grant from the Veterans' Administration, 104 of the 232 patients with carcinoma of the testis who survived after treatment at Walter Reed General Hospital during the war were brought back to that hospital for periods of 2 weeks each. Here, they were subjected to a total of 290 tests designed to study late radiation effects on the whole body and to evaluate complications of treatment and the so-called current performance status of these patients. This remarkable opportunity for posttreatment study resulted in the determination of the incidence of injuries and thus of the tolerance doses of the supervoltage radiation for the normal stomach (chart 3), transverse colon (chart 4), kidney (table 4), central nervous system (table 4), and other organs (*6, 8, 10, 12, 13–15, 21–23*).

CHART 4.—*Type and incidence of injury of transverse colon in relation to dose of supervoltage radiation therapy*



seldom severe, and their occurrence is outweighed by the increased destruction of the tumor accomplished by supervoltage X-ray therapy.

Late reactions, on the other hand, are more severe. They may include telangiectasis and contraction of the bladder mucosa with hematuria; chronic pelvirectal fibrosis, with secondary involvement of the rectum; indurated intrinsic rectal ulceration; intestinal injury manifested histologically by destruction of the epithelium, atrophy, and replacement fibrosis; intestinal perforation; radiation nephrosis; and injuries of the stomach ranging from barely demonstrable lesions causing dyspepsia to ulceration with perforation (p. 226).

HODGKIN'S DISEASE

A total of 216 patients with Hodgkin's disease were treated in the Radiation Therapy Section at Walter Reed General Hospital during World War II between 1942 and 1946 inclusive (*5*, *16*, *24*, *25*). They were segregated in a separate ward since frequently as many as 40 were undergoing treatment at one time.

Development of Therapeutic Regimen

Prewar studies had suggested that two changes in the therapeutic regimen might improve the results in this condition:

1. *Aggressive radiation therapy.* At the outbreak of World War II there were two divergent schools of thought concerning radiation therapy. Those who advocated conservative treatment, and who were then in the majority, believed in repeated small courses of radiation therapy, in the dosage range of 400 to 1,000 r, given not with the idea of destroying a particular group of lymph nodes but merely with the idea of keeping them quiescent. The fallacy of this policy was that the disease tended to recur in the treated nodes, and that the nodes, with each recurrence, became more radioresistant and required successively larger doses or X-rays for their control. Often the total amount of radiation delivered to a particular area under this so-called conservative treatment was greater than the total amount delivered by a different scheme by the advocates of radical treatment. The incidence of late burns and ulcers was often considerable after conservative treatment, and survival rates were not impressive.

The advocates of radical therapy, among them the Chief of the Radiation Therapy Section at Walter Reed General Hospital, took the reverse position. Colonel Friedman was able to prove his case statistically and clinically by the large number of patients handled at this hospital (fig. 59 and table 5).

2. *Selection of the proper tumor dose for each patient.* Prewar studies had indicated that the most efficient way to treat Hodgkin's disease and to eradicate the affected lymph nodes was not by the use of a standard dose in all cases but by varying the dose. These variations might range from 1,500 r in 1 week to 3,500 to 4,000 r over a 3- to 4-week period, depending upon the radiosensitivity or the radioresistance of the disease (chart 2).

TABLE 5.—*Survivals in 214 cases of Hodgkin's disease based on date of first deep X-ray treatment* [1]

Stage of disease	Number of cases	5-year survivals [2]	10-year survivals
I	48	24	6
II	32	14	3
III	136	44	6
Total	216	82	15

[1] Exclusive of two cases lost to followup.
[2] 10-year survivals included.

Routine of Management

At Walter Reed General Hospital, all patients with Hodgkin's disease were classified as to the stage of the disease before treatment was begun:

1. In stage I, the disease was limited to a single group of lymph nodes

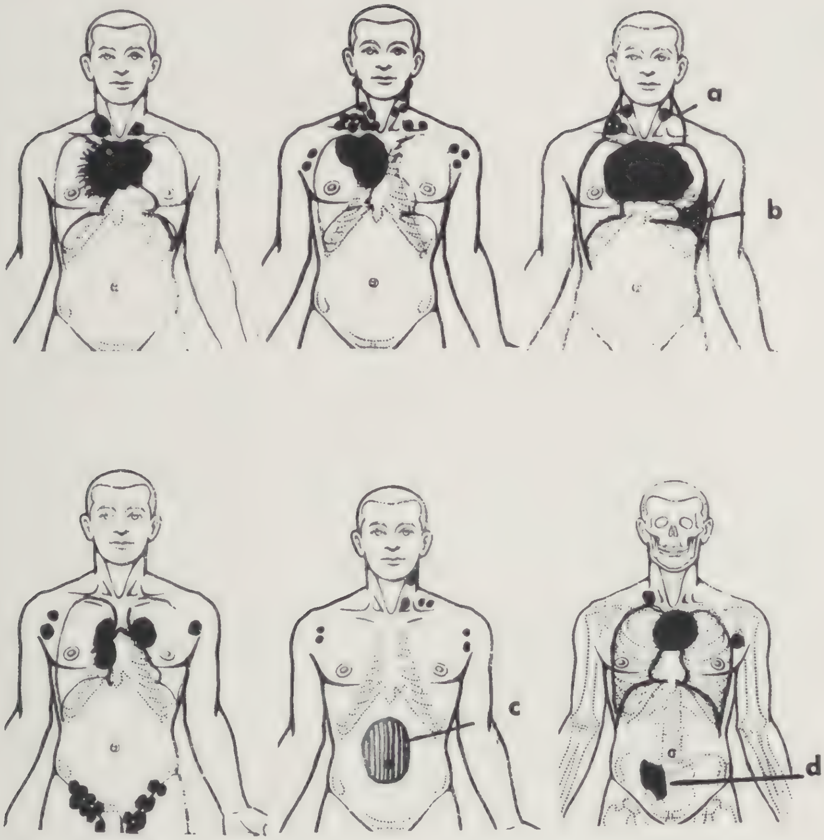


FIGURE 59.—Anatomic distribution of lesions of Hodgkin's disease in six patients with stage III disease, who survived more than 5 years after radical radiation therapy: Fullness (a), fluid (b), deep mass (c), and sacral involvement (d).

or to a single lesion in a single organ. There were no constitutional symptoms.

2. In stage II, the disease was limited to two adjacent groups of lymph nodes or to a single visceral lesion with regional lymph node involvement. Constitutional symptoms might or might not be present.

3. In stage III, two or more separated groups of lymph nodes, or multiple groups of nodes, were involved; or more than one organ was involved; or groups of lymph nodes and multiple organs were involved. Constitutional symptoms were almost always present.

When a patient with Hodgkin's disease was first treated, he received, regardless of the stage of his disease, a test dosage of 1,500 to 2,000 r over a 7-day period, applied to one group of nodes. The clinical response of the treated group of nodes to the test dose determined whether the tumor dose should be small (1,500 r) for all other nodes, moderate (2,500 r), or large

(3,500 r). From the practical point of view, the size of the dose determined whether a particular patient would require a course of treatment consisting of 25, 50, or 75 applications of X-ray, which would require periods of hospitalization varying from 1 to 4 months.

In every case, X-rays were applied not only to the involved areas but also, prophylactically, in the same dosage, to uninvolved cervical, axillary, and inguinal lymph nodes, and, electively, to the mediastinal and abdominal lymph nodes.

The time-dose studies (isoeffect recovery curve) developed at Walter Reed General Hospital were first worked out in Hodgkin's disease (chart 2). The smaller doses shown on the curve were used on superficial lymph nodes in the cervical, axillary, and inguinal regions. The larger doses were applied to deep-seated mediastinal and abdominal nodes, for which it was early learned that supervoltage radiation supplied the only really efficient treatment.

The technique described spared the skin, and the greater depth dose permitted the administration of smaller skin doses per portal. Also, the total tumor dose applied to each area could be given in shorter periods of time, which permitted a still further reduction in the overall treatment time and in the required tumor dose.

All patients at Walter Reed General Hospital, regardless of the stage of their disease, received aggressive radiation; that is, they were given the maximum doses which, it was estimated, were required to eradicate the disease from the treated nodes for the remainder of their lives. Recurrences were observed in the nodes thus treated in some 10 percent of the fatal cases, but only in the terminal phases. No recurrences were observed in the patients who survived, nor was there any evidence of lymph node recurrence in many autopsies on patients who ultimately died from the constitutional effects of their disease.

In 1945, a few patients with Hodgkin's disease were treated with nitrogen mustard by the Radiation Therapy Section in conjunction with the Medical Service. Transient shrinkage occurred in some nodes, but early recurrence was the rule.

Followup

In October 1953, a followup of the 216 patients with Hodgkin's disease treated at Walter Reed General Hospital during the war years showed, based on the date of onset, 24 survivals for 10 years (11 percent of the total number) and 73 other survivals for 5 years or more (44 percent) (*25*). Based on the date of the first X-ray treatment (table 5), there were fifteen 10-year survivals and, including these 15 cases, eighty-two 5-year survivals (37 percent). These excellent results are enhanced by the fact that 136 patients (63 percent of the total number) were in stage III when they were first seen. The longest survival in the series from the date of onset was 18 years.

The only results in Hodgkin's disease similar to those obtained at Walter Reed General Hospital were obtained at the Toronto Cancer Institute, where

a similar technique was developed independently (*26*). The most valuable product of the studies at these two institutions is the proof that aggressive supervoltage radiation therapy is the most efficient method of treatment in all stages of Hodgkin's disease, including most cases in which constitutional symptoms are present, and that this technique yields much longer survival rates than are achieved by any method previously employed.

MALIGNANT DISEASE OF THE TESTIS

Before World War II, the life history of tumors of the testis was not well understood; the pathologic classification was confused; radiotherapeutic techniques were variable and uncertain; and the cure rates, even in the hands of the best urologic surgeons, were very low. Hinman (*27*), in 1933, developed radical retroperitoneal lymph node dissection, but the results were so discouraging in the small series of cases in which he employed it that he soon abandoned the technique. Maj. (later Col.) Lloyd G. Lewis, MC, Chief, Urology Section, Walter Reed General Hospital, used the method on a few advanced cases in 1942, with the same results: The patients died just as promptly as those not submitted to this procedure.

The amount of material available at this hospital between May 1942 and September 1946, 232 tumors of the testis, permitted the development of a combined surgical-radiation technique that produced better results than had ever before been achieved in this condition (table 6) (*9, 10, 13, 15, 22, 23, 28, 29*). The basis of the good results was the excellent cooperation that existed between Major Lewis and Major Friedman.

TABLE 6.—*Five-year arrests in 232 cases of carcinoma of testis*

Type of growth	Number of cases	Five-year arrests	
		Number of cases	Percentage
Seminoma	94	78	83
Trophocarcinoma	53	13	25
Teratocarcinoma	66	28	42
Teratoma	7	6	86
Others	12	10	83
Total or average	232	135	58

Histologic Classification

The program began with the extension of Friedman's prewar studies of the histologic effects of X-rays on squamous cell carcinoma of the mouth and pharynx (*18, 19*) to tumors of the testis. To determine the total tumor dose necessary for each patient, a preliminary test dose (ranging from 500 r in 1 week to 1,000 r in 2 weeks) was given to the tumor of the testis before

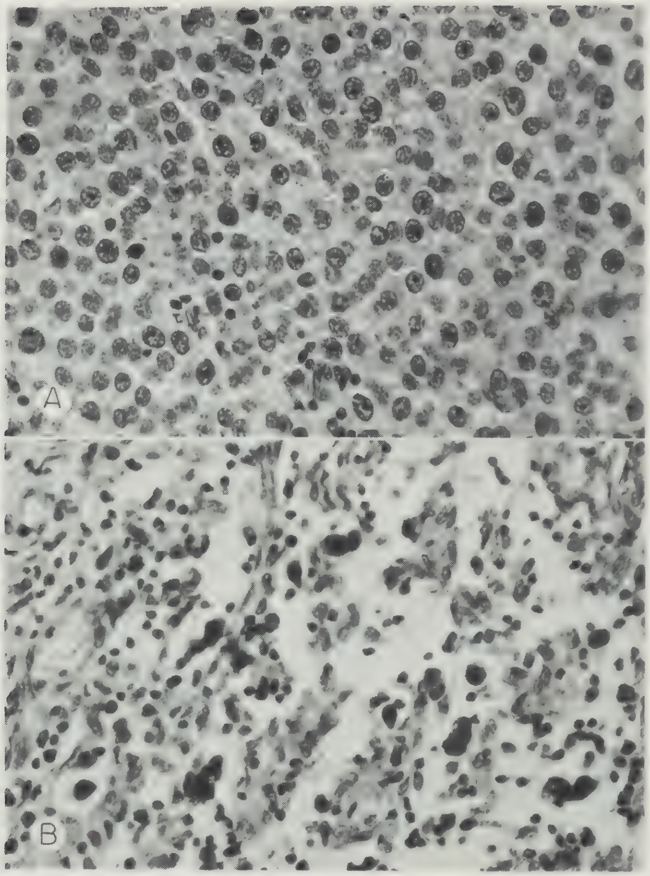
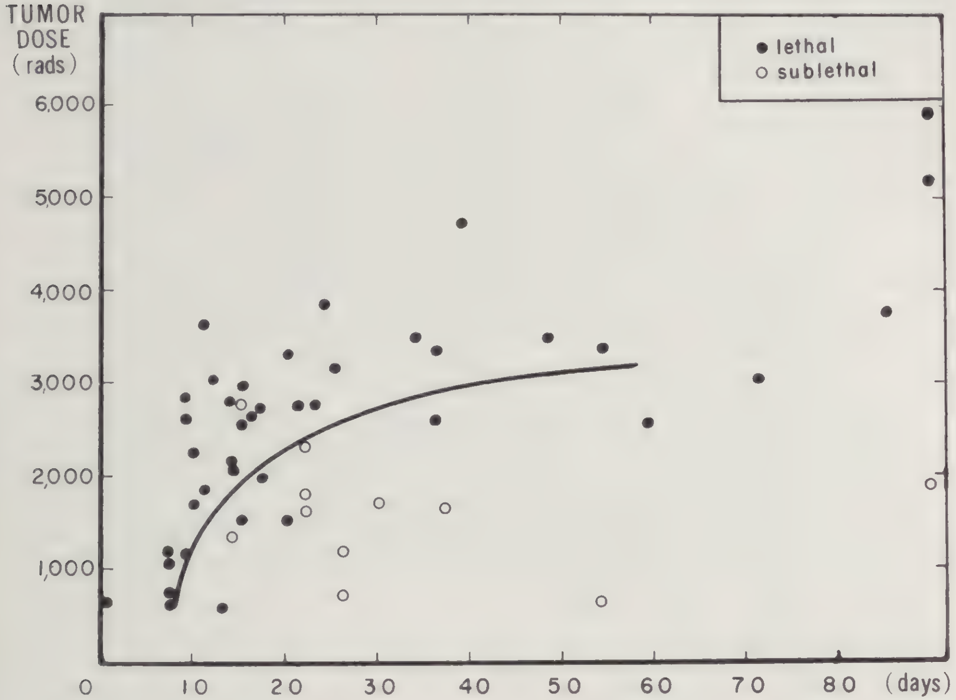


FIGURE 60.—Histologic appearance of typical seminoma of testis. A. Before treatment. B. After tumor dose of 870 r in 3 days. Tumor, when removed on fourth day, was found to be almost completely destroyed.

orchiectomy, and the results were evaluated histologically with respect to the effects of different doses on different types of tumors. It soon became evident that seminoma of the testis, which made up about 40 percent of all tumors of the testis, was extremely radiosensitive (fig. 60 and chart 5) while other tumors in this location were relatively radioresistant and required large—often dangerously large—doses of radiation for their control and eradication (fig. 61 and chart 6).

During the course of this histologic investigation, there was identified in the Army material a tumor containing embryoma bodies which resembled 12-day-old blastocysts in a normal pregnant female (fig. 62). From this beginning, the following classification of tumors of the testis was devised by Major Friedman and Major Lewis:

CHART 5.—*Isoeffect recovery tumor dose curve for seminoma of testis based on test X-ray doses given in 51 lesions* [1]



[1] Most doses below the average regression curve were sublethal, while those above were lethal.

1. Seminoma (histogenetic stem cells uncertain).
2. Trophocarcinoma (generally termed embryonal carcinoma). This tumor is a primitive, malignant placental tumor derived from primordial trophoblasts and presenting different histologic pictures as it recapitulates neoplastically the development of the placenta. The different histologic pictures in this group include undifferentiated trophocarcinoma, adenotrophocarcinoma, papillary trophocarcinoma, choriopapillary trophocarcinoma, and chorioepithelioma.
3. Teratoma.
4. Teratocarcinoma, a combination of teratoma and trophocarcinoma, only the latter component being malignant.
5. Interstitial cell tumors and other tumors amenable to surgery.

Techniques of Treatment

Analysis of the data secured in the histologic studies just summarized led to the development of a combined surgical-radiotherapeutic regimen carried out as follows:

1. A preliminary test dose of X-rays was applied to the testis.

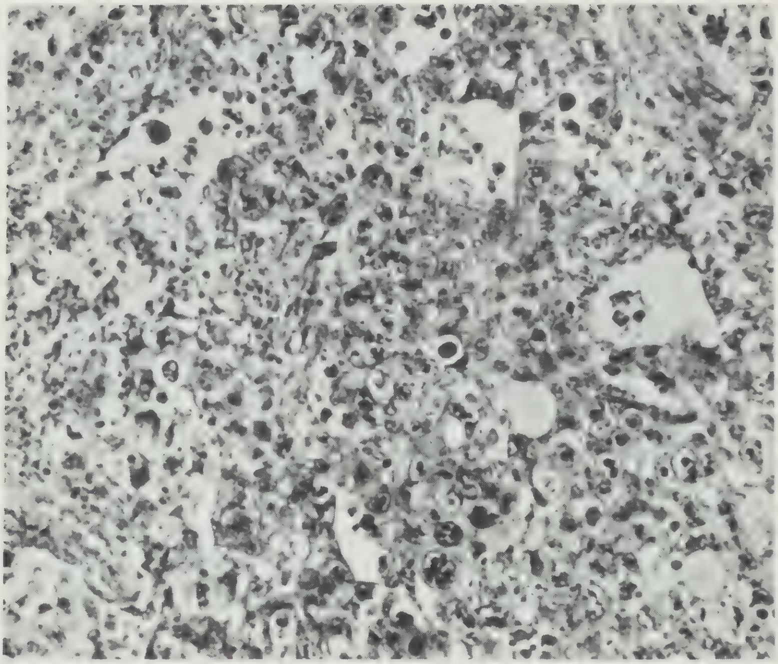


FIGURE 61.—Histologic appearance of undifferentiated trophocarcinoma of testis showing very few changes after X-ray tumor dose of 1,000 r. It was ultimately shown (cf. chart 6) that 4,000 r were required for eradication of this type of tumor.

2. Orchiectomy and radical retroperitoneal lymph node dissection were carried out when the nodes were either not demonstrable or very small. The improved surgical techniques which Colonel Lewis developed for these operations are now (1965) standard procedures.

3. A week after operation, radiation was applied to the retroperitoneal area, the dosage depending upon the histologic diagnosis of the tumor and the result of the test dose.

4. If the testis had previously been removed, the dosage to be used was determined from the table of lethal tumor doses devised by Friedman (*4*).

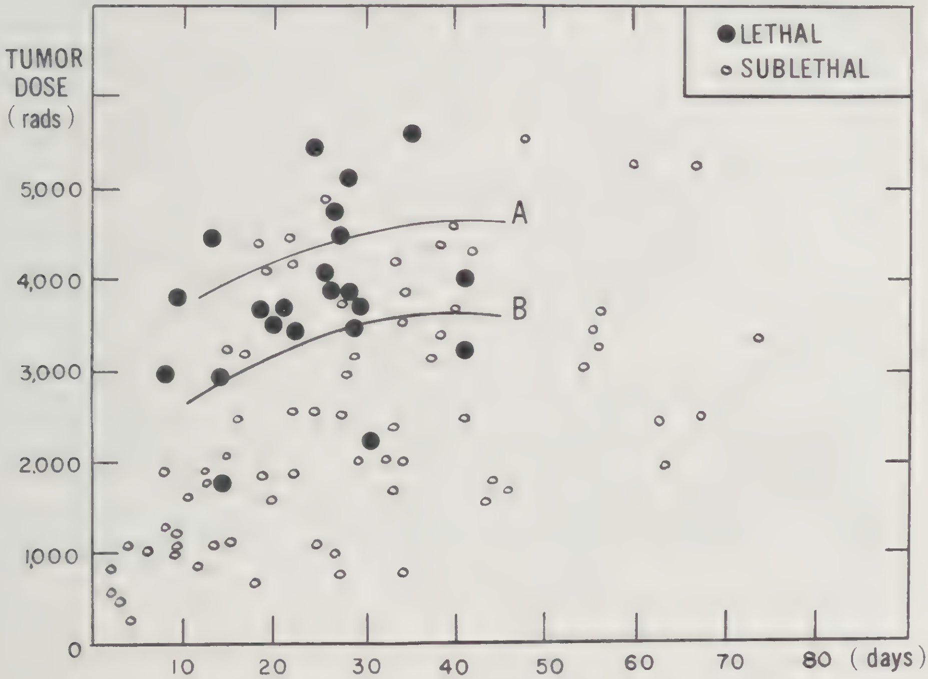
The following dosages were used:

1. The average tumor lethal dose for seminoma of the testis ranged from 1,000 r delivered over 10 days to 2,500 r delivered over 20 days.

2. Occasionally, a moderately radiosensitive trophocarcinoma of the testis could be eradicated with doses as low as 2,500 r given over 10 days, but the usual range was from 3,500 r in 10 days to 4,500 r in 40 days. The radiosensitivity or radioresistance of these tumors could be determined only by a preliminary test dose.

3. The dosage used to destroy adult teratoma was the same as that neces-

CHART 6.—*Scatter diagram based on 91 known tumor doses of supervoltage radiation therapy in 83 cases of trophocarcinoma of testis* [1]



[1] Isoeffect recovery tumor dose, curve A, depicts recommended dosage range. However, this dose, delivered by 2-portal crossfire technique, will produce radiation injury of stomach or intestines in 25 percent of all cases. Doses shown in curve B will produce no injury but will be inadequate to destroy some tumors (cf. chart 3).

sary for the normal tissues which they simulated. The tumors were as radiosensitive or as radioresistant as these analogous normal tissues.

4. In most teratocarcinomas, metastatic disease in the retroperitoneal lymph nodes occurred as some form of trophocarcinoma. The tumor lethal doses were those used for trophocarcinoma. When teratomatous elements were found in metastatic lymph nodes, appropriately larger lethal doses were used.

5. Conventional deep X-ray therapy apparatus could be used in the delivery of small doses of X-rays to tumors of the testis, especially for seminoma, as the experience at Lawson General Hospital (*30, 31*) and at certain other general hospitals showed, but supervoltage radiation therapy was more effective, if only because it produced few if any skin reactions. Radioresistant tumors, such as trophocarcinoma and teratocarcinoma, could be treated efficiently only with supervoltage X-rays which were required to deliver doses of approximately 4,000 r to the retroperitoneal area. With this equipment, it was possible—it would otherwise have been impossible—to

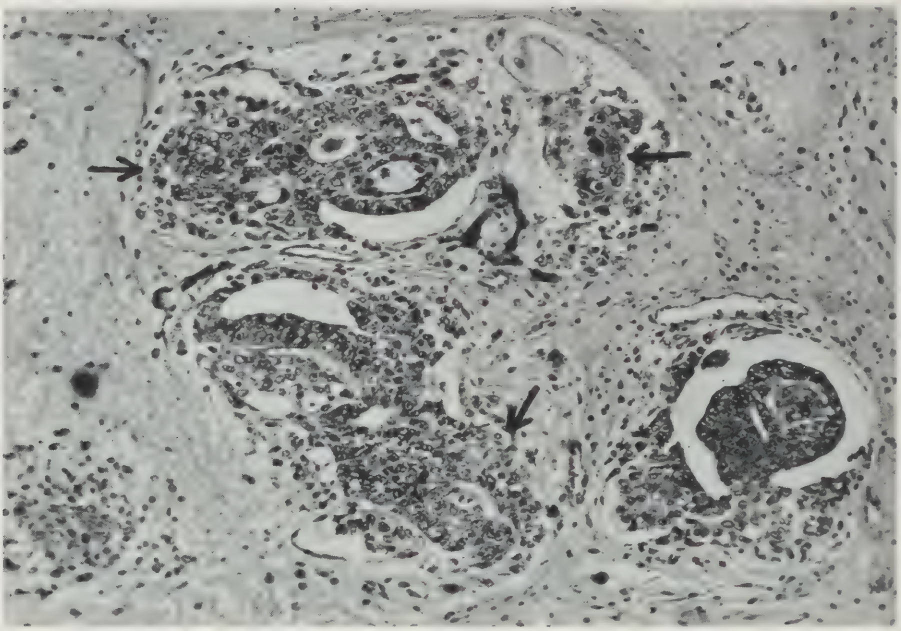


FIGURE 62.—Histologic appearance of tumor of testis composed of abnormal blastocysts resembling those of a 10- to 12-day-old embryo. This tumor, first of the kind identified in Walter Reed General Hospital material, served as a basis for histologic classification of tumors of the testis and their treatment by supervoltage radiation therapy.

deliver such dosages through single anterior and posterior abdominal fields. There was a certain amount of radiation sickness associated with such therapy but, on the whole, it was well tolerated.

Radiation Injuries

By the end of 1944, the techniques just described had been employed on a large series of patients with malignant disease of the testis, with encouraging results from every standpoint, including the absence of evident sequelae. Early in 1945 the outlook changed. A patient with metastatic, inoperable retroperitoneal metastases containing normal bone and intestinal structures was given a tumor dose of 6,000 r over 33 days, with no immediate side-effects. Three months later, however, he experienced, for the first time, acute abdominal distress, and partial gastrectomy had to be performed for a perforating ulcer of the gastric antrum (fig. 63).

This ulcer was the first of a series of totally unexpected late radiation injuries of the gastrointestinal tract in patients treated for malignant disease of the testis. The injuries, many of which manifested themselves after the patients had left the hospital, appeared at intervals ranging from 3 months

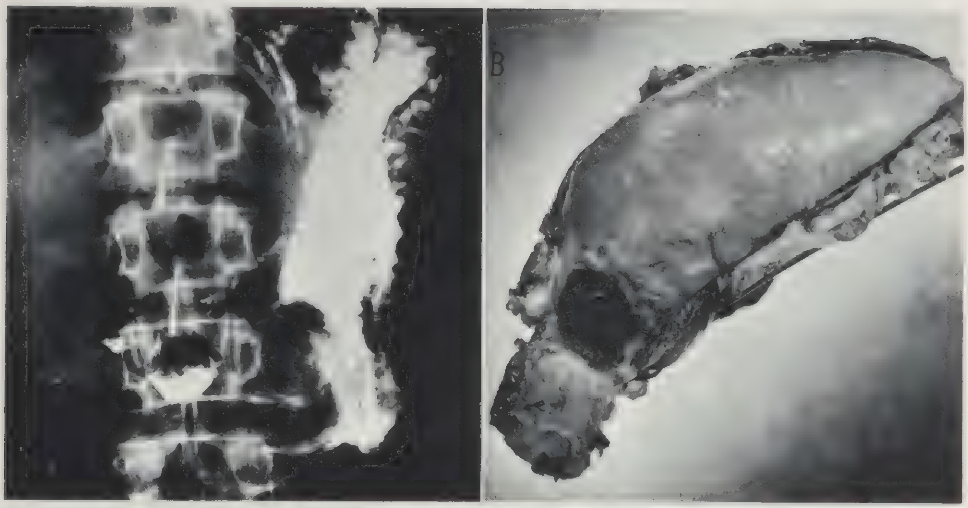


FIGURE 63.—Perforated gastric ulcer caused by radiation therapy. A. Anteroposterior radiograph of stomach 3 months after tissue dose of 6,000 r given in 33 days for metastatic teratocarcinomatous mass situated behind stomach. Perforating ulcer is clearly visible, with barium in lower half and air in upper half. B. Specimen removed at subtotal gastrectomy.

to 5 years after treatment. They took the form of dyspepsia; radiation gastritis demonstrable radiographically; and radiation ulcers, without (fig. 64) and with perforation. The severity of the gastric injuries depended upon the size of the radiation dose. Similar injuries were observed in the small and large intestines (fig. 65), but only after large doses of X-ray had been given.

Among the 232 patients with malignant tumors of the testis treated at Walter Reed General Hospital during World War II were 10 postradiation injuries of the spinal cord, ranging from mild to severe, and 3 osteogenic sarcomas of the spine. In all, 24 deaths were attributed partly or entirely to radiation injuries. The studies inspired by these injuries produced, in the postwar years, improved techniques that avoided damage to normal tissues (p. 215).

CARCINOMA OF THE BLADDER

At the outbreak of World War II, the cure (arrest) rates for carcinoma of the bladder were distressingly low, seldom exceeding 10 percent. It was not until almost the end of the war that a new technique of treatment was developed in the Radiation Therapy Section, Walter Reed General Hospital, by a plan originated by Major Lewis and Major Friedman (*32*). By September 1949, they were able to report that 12 of the first 13 patients treated by this method had been free of disease for periods ranging from 10 months

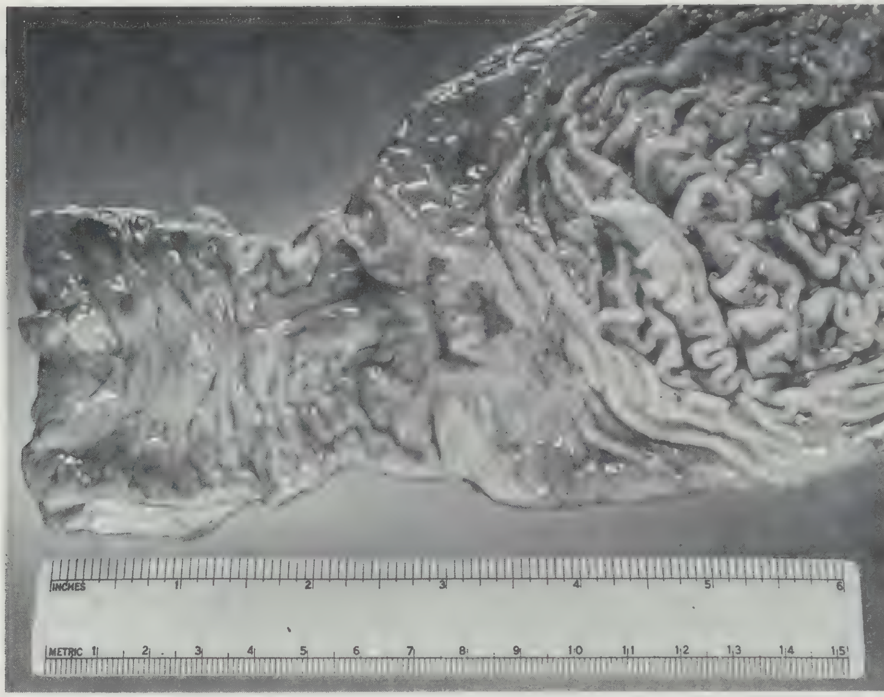


FIGURE 64.—Radiation ulcer of stomach without perforation.

to 4 years. It is important to note that all the patients in this group had true carcinoma of the bladder, as opposed to papillomatosis and so-called grade I papillary carcinoma.

The principle on which the new technique was based is simple, but its execution was complex. It required a great deal of time and attention on the part of the combined urologic-radiotherapeutic team. Probably for this reason more than any other, this method (known as the Walter Reed technique) is still not widely used, though at the present time (1965) it yields the highest 5-year cures of any method available. A recently studied series showed twenty-one 5-year arrests in 33 cases (chart 7). All cases were true carcinomas of the bladder, and in some there was extravesical extension. Results were not good, however, if the extension from the serosa exceeded 2 cm. (*33*).

The Walter Reed technique consists of the insertion into the bladder of a small central source of radium (or of radioactive cobalt available since the war), with the aid of an improved latex Foley catheter, which is blown up after it is inserted. The technique thus amounts to provision of a central source intracavity application of radiation (fig. 66)

Treatment was given in two sessions, at 7-day intervals. The first dose, 4,000 r over a 4-day period, was given routinely to all patients. Seven days later, the bladder was inspected and a biopsy was secured, the information

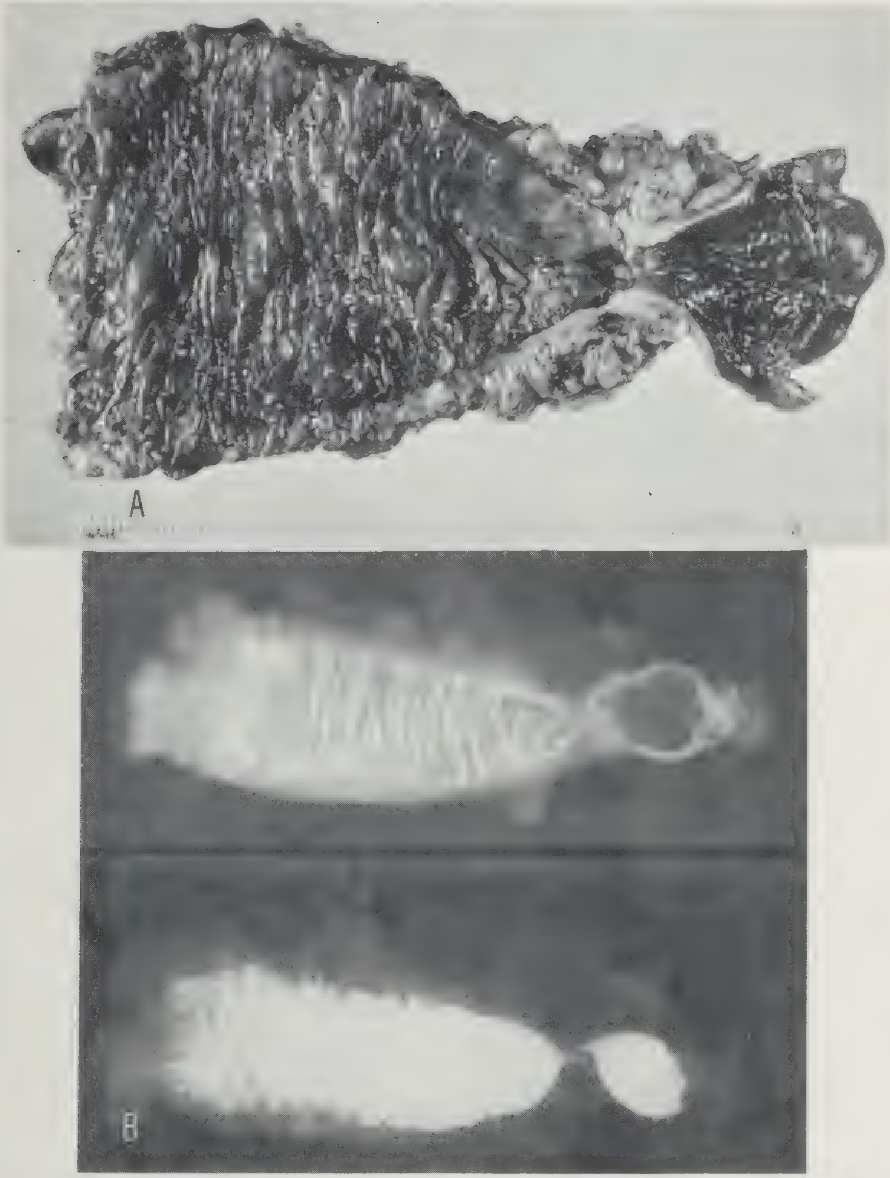
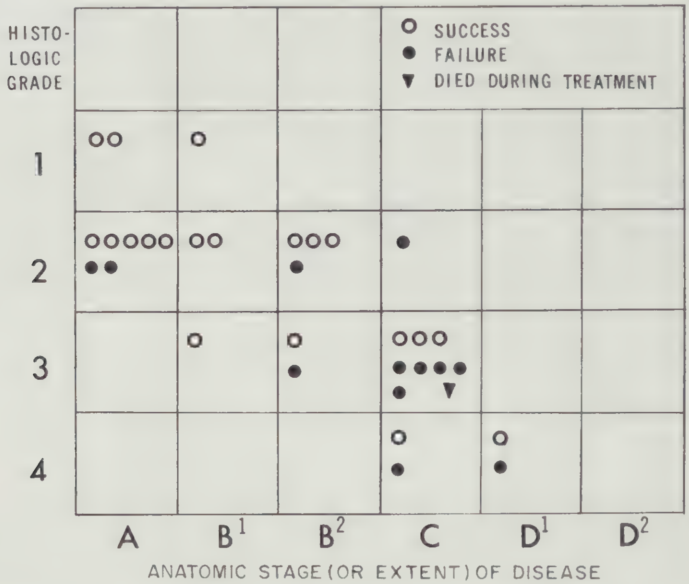


FIGURE 65.—Radiation injury of transverse colon. A. Section of transverse colon removed 3 weeks after sudden onset of symptoms of intestinal obstruction which occurred, for first time, 5 years after tissue dose of 5,000 r given over 6-week period for carcinoma of testis. Ringlike constriction was caused by radiation-induced maturation and hyalinization of submucosal loose connective tissue. There was no injury of mucosa or serosa. B. Radiograph of surgical specimen containing barium.

CHART 7.—*Five-year arrests in 33 patients with carcinoma of bladder classified according to anatomic stage and histologic (Marshall) degree of malignancy* [1]



[1] Anatomic stage of carcinoma: A—limited to mucosa and submucosa; B1—with superficial invasion of muscularis; B2—with extension to serosa; C—with extravesical extension; D1—with metastases to regional lymph nodes; and D2—with involvement of extrapelvic lymph nodes (there were no carcinomas in situ in this group).

derived from it determining the amount of the second treatment (fig. 67). In favorable cases, the second dose consisted of 2,000 r over a 2-day period, the total dose thus being 6,000 r. If the response to the first dose was less favorable, second doses of 3,000 to 6,000 r were given, for total doses of 7,000 to 10,000 r.

Doses of such magnitude were likely to produce severe local reactions immediately and possible later contraction of the bladder, but these complications were considered well worth risking in exchange for the increased rates of arrest just cited.

CARCINOMA OF THE CERVIX

The use of serial biopsies in carcinoma of the cervix revealed a wide range of radiosensitivity (*6*). When some patients with primary and recurrent cervical carcinoma were given supervoltage therapy preliminary to the usual radium treatment, serial biopsies showed such marked radiosensitivity that the tumors were completely destroyed in about 28 days, with total doses ranging from 4,000 to 4,500 r, and subsequent radium therapy was not considered necessary. On the other hand, some cervical carcinomas proved extremely

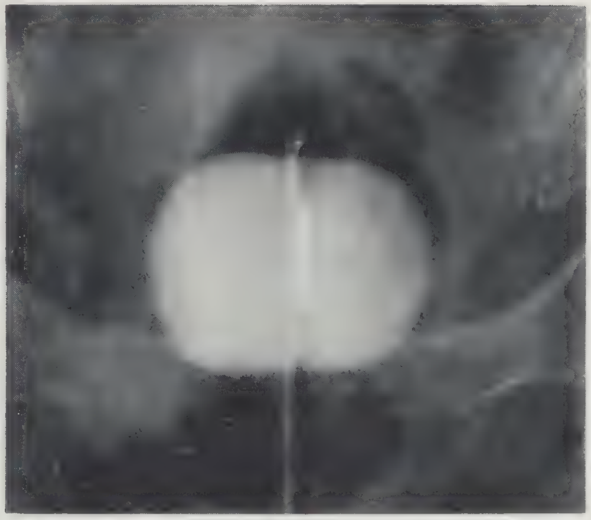


FIGURE 66.—Radiographic demonstration of Walter Reed technique for carcinoma of bladder, showing 25-mg. radium capsule inside Foley catheter in bladder, left in situ for 4 days, to give initial dose of 4,000 gamma roentgens. A cystoscopic biopsy is taken at the end of 7 days, after which initial treatment is repeated. Total tumor dose is approximately 8,000 gamma roentgens in 15 days.

radioresistant; they persisted in spite of very large doses of both X-rays and radium, and surgical removal was necessary. In general, about 20 percent of cervical neoplasms were extremely radiosensitive and about the same proportion were extremely radioresistant.

It was found that the laws of radiosensitivity do not apply in carcinoma of the cervix. Paradoxically, the more differentiated and keratinized the tumor was, the more radiosensitive it proved to be, whereas many undifferentiated anaplastic growths, which showed considerable pleomorphism and mitoses, were relatively radioresistant.

OTHER RESEARCH PROJECTS

In addition to the major research projects just described, other studies were initiated in the Radiation Therapy Section, Walter Reed General Hospital, during World War II and were completed later in civilian institutions. They included:

1. The treatment of carcinoma of the maxillary antrum by a central radium source.

2. The treatment of carcinoma of the parotid, laterally located intraoral and pharyngeal carcinoma, metastatic cervical lymph nodes, and carcinoma

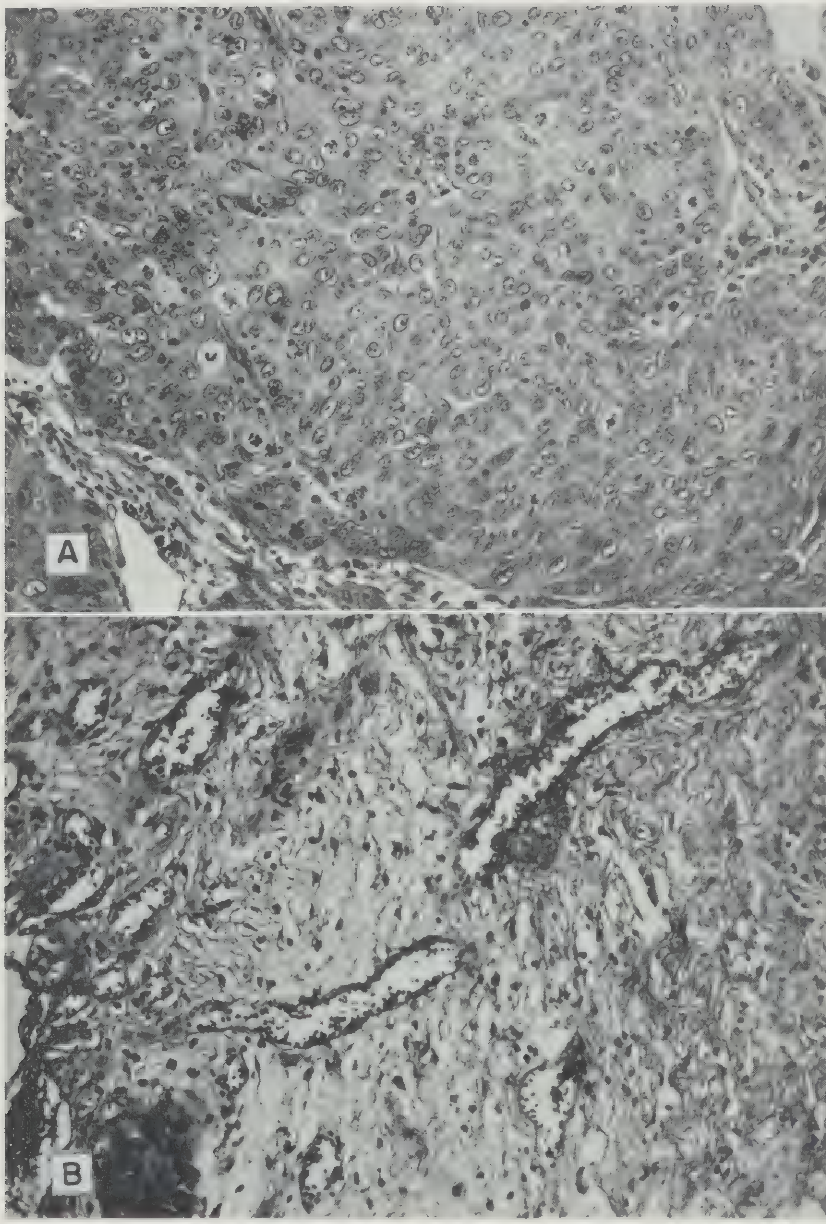


FIGURE 67.—Infiltrating carcinoma of bladder. A. Histologic appearance of tumor before treatment. B. Histologic appearance of specimen secured on 11th day after treatment with tumor dose of 4,000 r in 4 days. This extremely radiosensitive tumor was almost completely destroyed on the first course of treatment.

of the breast recurrent on the chest wall by a single-portal-massive-dose technique (*11*).

3. The treatment of inoperable carcinoma of the prostate by perineal exposure and insertion of radium needles.

4. The treatment of bulky hemangiomas in infants with double-threaded removable platinum radon implants.

5. Studies on tumor dosages for lipoid histiocytosis of the bone.

Exhibits of work done at Walter Reed General Hospital and presented after the war included:

1. Testis Tumors, at the American Urological Society in 1946.

2. Radiation Injuries and Tolerance Dose of Normal Stomach, at the American Roentgen Ray Society in 1946.

3. Million-Volt Irradiation of Normal Tissues; Late Effects and Tolerance Dose, at the American Roentgen Ray Society in 1951.

These three exhibits won prizes or certificates when they were shown.

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Part III

MEDITERRANEAN THEATER OF OPERATIONS

CHAPTER IX

The Mediterranean (Formerly North African) Theater of Operations

James E. Lofstrom, M.D.[1]

Section I. Administrative Considerations

HOSPITAL ORGANIZATION AND FUNCTIONS

The military operations in North Africa, which began in November 1942, furnished the first real test of radiologic capacities and potentialities of the U.S. Army in World War II. In the accomplishment of their primary mission of service to other Army medical personnel in the first major land-based offensive combat in which U.S. troops engaged, radiologists in field, evacuation, station, and general hospitals began to learn the techniques which they would use in later months and years of the war. The Sicilian operation was at once "a proving ground for the lessons learned in Africa and a dress rehearsal for Italy" (*1*). The experience in Italy provided valuable lessons for the invasion of the Continent from the United Kingdom. The Senior Consultant in Radiology in ETOUSA (European Theater of Operations, U.S. Army), Lt. Col. (later Col.) Kenneth D. A. Allen, MC, visited MTOUSA (Mediterranean Theater of Operations, U.S. Army) late in 1943 and secured data on the basis of which he made important changes in the provision of equipment and the disposition of personnel before D-day in Normandy (p. 419).

At the beginning of the war, the radiology department in hospitals in NATOUSA (North African Theater of Operations, U.S. Army), as elsewhere, was frequently a part of the section of surgery, as had been the practice between the wars. In the course of the war, radiology came to be recognized as a separate section and to be established as such. In only a few instances, because of X-ray encroachment upon facilities which surgical sections no longer controlled, did the new arrangements give rise to difficulties. The change was beneficial in many ways. one being that the chief of the section of radiology, because his new position brought him into direct contact with

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[1] This chapter was prepared with the invaluable assistance of Clark R. Warren, R.T., now Technical Director, Department of Radiology, Detroit Memorial Hospital, Detroit, Mich., and formerly a technical sergeant assigned to the 36th General Hospital. He assisted in the preparation of the material, provided a number of special items, and also provided the enlisted man's point of view, which is always useful. His knowledge of photography was responsible for many photographs and radiographs taken during the war in the Mediterranean theater.

the hospital commander, was able to operate more efficiently and render better service.

While all radiology sections were conducted under certain general principles, each section developed its own individual methods for processing requisitions, handling patients, filing records, and disposing of roentgenograms. Some of these practices were based on previous civilian experience; others evolved out of the exigencies of the logistic situations that had to be faced.

The special problems that arose in various hospitals depended more upon their missions at the particular time than upon the types of installations they represented. Hospitals operating in forward areas and receiving wounded directly from clearing stations solved their organizational problems in one way; when the same hospitals operated in rear areas and received wounded from forward hospitals, they had different problems and solved them differently.

Departmental Operations

When a hospital operated behind a combat zone, with large numbers of casualties often being admitted around the clock for days on end, X-ray personnel had to be divided into shifts to handle the work because of deficiencies in T/O (table of organization) allowances. Even with these arrangements, personnel sometimes had to be augmented by personnel of other sections. Shortages were particularly notable in evacuation hospitals. In contrast to forward hospitals, fixed hospitals in the rear usually operated on much the same schedule as civilian hospitals.

X-ray examination as a triaging procedure for casualties admitted to forward hospitals from clearing stations had only a limited application. Of necessity, the more seriously wounded patients, who required immediate surgery, had to have priority. During periods of stress, therefore, with a heavy influx of casualties, routine roentgen evaluation for triaging purposes had to be abandoned. With even greater pressures, it was found necessary to resort to simple fluoroscopy rather than radiography to expedite the handling of the wounded. When the stress was relieved and sufficient personnel were available, the elective use of X-ray as a triaging method was again employed and proved of value. Patients were then, as a rule, assigned more accurately to the clinical services. In spite of conscientious efforts at triage, however, ridiculous errors occasionally occurred as when, for instance, a patient with a fracture of the incus was admitted to a 250-bed orthopedic ward.

Auxiliary Radiologic Teams

It became evident early in the North African operation, as just indicated, that staffing was inadequate in the X-ray departments of evacuation hospitals when they received large numbers of casualties. Two officers simply could not handle the load, and assignment of personnel from other sections of the

hospital was not a satisfactory solution: It usually resulted in the placement in the X-ray section of a medical officer who, although he had no radiologic background, was called upon to make major radiologic determinations.

When Colonel Allen visited the theater and observed the situation just described, he made the excellent suggestion that auxiliary radiologic teams be established, to furnish the necessary assistance during times of stress. He instituted this plan in the European theater, where it proved extremely successful (p. 407), but it was never adopted in the Mediterranean theater.

Military Considerations

In field and evacuation hospitals particularly, and in station hospitals, the tendency was toward informality in working relations (fig. 68). During periods of heavy activity, professional and technical personnel were hard pressed, and all their attention was devoted to the immediate care of their patients. In fixed hospitals, while the pressure was generally less, the arrival of 300 to 600 patients by hospital train invariably brought a large influx of work to the radiologic department.

This situation sometimes produced a conflict of interest. Fixed hospitals, particularly the large general hospitals, were subject to inspection by visiting dignitaries, and it was therefore the custom to enforce rules of military courtesy and discipline rather rigidly, and to require close order drill as well as professional activities. If the arrival of a hospital train and the visit of a general officer coincided, the question of precedence arose.

In one hospital, the matter was settled after a detachment commander, with a temperature of 103° F., had lain on a litter for 2 hours, in a drafty corridor, while radiologic personnel were attending a review for a visiting general officer. Next day a bulletin was posted in this hospital, excusing all X-ray personnel from drill, military lectures, and other nonmedical and nontechnical responsibilities. The end result was that while the military ratings of this unit deteriorated, since enlisted men of the least qualifications, such as those assigned to outdoor work and garbage detail, thereafter represented it at reviews, its technical and professional performances were greatly improved.

AFFILIATED HOSPITALS

As of December 1943, the staffs of all 24 general hospitals in the North African theater and 4 of the 6 evacuation hospitals were members of the faculties of medical schools or, in a few instances, of the staffs of outstanding general civilian hospitals. All sections of the country were represented in these affiliated hospitals, and the wide geographic distribution provided a variety of viewpoints that was stimulating and desirable.

In addition to the specialists in various medical fields, affiliated units also

FIGURE 68.—X-ray office, 8th Evacuation Hospital, Teano Area, Italy. Capt. John R. Mapp, MC, working with clerk in temporary, congested quarters.

included personnel with special qualifications and experience in other fields. Among them were nurses and registered X-ray and other technicians.

Many nonaffiliated units were, of course, competently staffed, but few of them had such concentrations of talent as the affiliated units, many of whose staff members, incidentally, were beyond the age at which they would ordinarily have been in service.

The performance of these hospitals bore out, beyond question, the great value of bringing together in military practice specialists who had worked together in civilian life. Their cooperation was carried over into the military experience, and numerous scientific contributions proved the soundness of the longtime partnership. Many of the new techniques evolved at these hospitals were predicated upon the production of radiographs of high quality—often in circumstances that were distinctly unfavorable—and upon their intelligent interpretation by staff radiologists. At the 36th General Hospital, for instance, neurosurgeons and radiologists cooperated in important studies of wounds of the head (p. 278) and of the spine (p. 289). Similarly important studies were also made on chest wounds at this and other affiliated hospitals (p. 290).

In the European theater, many affiliated units necessarily suffered serious

attrition in advance of the Normandy landings, their excess of professional talent being drained off to raise the level of personnel in less fortunate hospitals. Very few such transfers were made in the Mediterranean theater, particularly in departments of radiology. Many of the personnel of these hospitals had entered service with the tacit understanding that they would not be moved without their consent. When, however, the need for such transfers did arise in MTOUSA, there was always a generous response to the call for officers, particularly after the unit had been in operation for several months. Most affiliated hospitals then considered it an honor to be asked to supply officers for posts of greater responsibility in other units. On the other hand, a number of officers who could have secured higher rank by transfer declined the promotions and elected to stay with their parent hospitals.

HOSPITALS FOR SPECIAL TREATMENT

Centers for specialized treatment were first set up in the North African theater, where the plan was practical because of the concentration of specialized personnel or the fortuitous location of specialized equipment. They provided better care for casualties, with less loss of time and faster disposition. Their success in North Africa contributed to their becoming Medical Department policy. There were, of course, no special centers for radiology, as such, other than the radiotherapy center at the 17th General Hospital (p. 317), but it is not necessary to elaborate upon the importance of the radiology section in centers devoted to neurosurgery, thoracic surgery, maxillofacial injuries (plastic surgery), and tuberculosis, among other specialties.

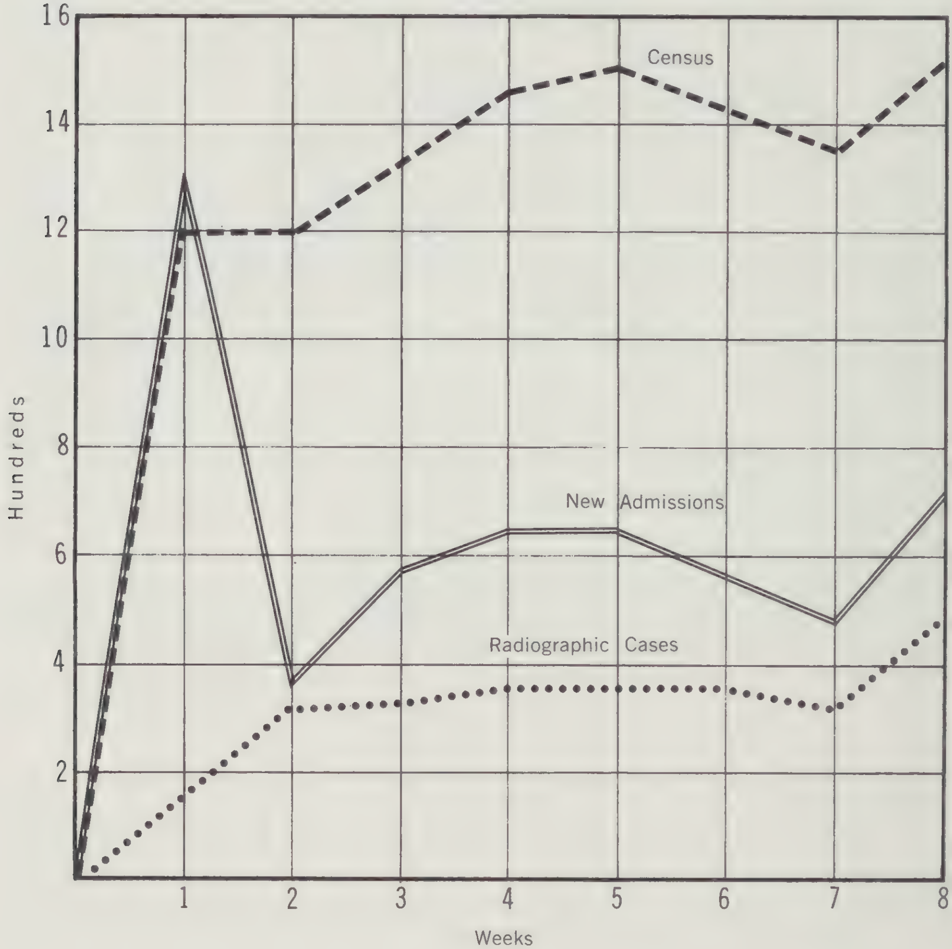
Reconditioning centers were also established in the Mediterranean theater, the first at the 105th Station Hospital, in the Eastern Base Section, in February 1944. The major concern of these centers was physical rehabilitation, and the X-ray department was called upon to provide not only routine service but additional specialized studies for the evaluation of disabilities. Its function in reconditioning centers was further illustration of the broad application of diagnostic radiology in the total care of combat casualties.

Dental radiography was also of great importance in these centers, in which a great deal of reparative dental work was performed.

CASELOAD

All X-ray sections in MTOUSA, as in other theaters, were subjected to periods of furious activity, followed by lulls. This was especially true in forward installations, in which the X-ray department was often employed only for screening casualties. Fixed hospitals in rear echelons carried on the type of work common in general hospitals in civilian life. While they also carried the heavy load of evacuated casualties, their workload was relatively even and lacked the emergency character of work in forward hospitals. Only

CHART 8.—*Relation of X-ray examinations to weekly admissions and weekly census, 36th General Hospital, 11 November 1943–1 January 1944*



in rest centers and convalescent hospitals was the use of X-ray disproportionately low; in reconditioning centers, as just mentioned, it was used with remarkable frequency.

Although workloads in all hospitals varied appreciably according to logistic circumstances, the overall relation of X-ray studies to total patient admissions and weekly hospital census remained surprisingly constant (chart 8). Numerical data for the 7 weeks of operation at the 36th General Hospital covered by this chart are shown in table 7. The 2,481 radiographic examinations were made on 2,319 patients, 1,848 of whom were new admissions.

Another typical example of the workload of a general hospital appears in table 8, which breaks down three periods of activity for the 12th General

TABLE 7.—*Radiologic examinations, 36th General Hospital, 11 November 1943–1 January 1944* [1]

Area of examination	Number of examinations
Head	101
Sinuses	54
Mastoids	5
Facial bones	4
Mandible	5
Ventriculograms	3
Chest	758
Bronchograms	6
Heart	10
Clavicle	22
Abdomen	55
Gastrointestinal:	
Esophagus	11
Stomach	169
Barium enema	81
Gallbladder	41
Genitourinary:	
KUB	20
Retrograde pyelograms	53
Intravenous pyelograms	5
Pelvis	19
Hip and femur	70
Spine:	
Cervical	41
Thoracic	62
Lumbar	99
Lumbosacral	151
Sacrum	24
Coccyx	3
Extremities	588
Miscellaneous	21
Total	2,481

[1] During this period, 41 fluoroscopic examinations were carried out.

Hospital. During part of this time this hospital served as both a neurosurgical and a thoracic surgery center. The number of chest examinations was exceeded only by examinations of the extremities. During the periods these 25,416 diagnostic studies were made, this hospital admitted 27,609 patients and cared for 21,909 outpatients.

The lack of a full-time consultant in radiology for the Mediterranean theater explains the lack of general data for it. When Colonel Allen visited the theater in October 1943, his observations permitted certain statistical generalizations applicable to radiology:

1. About 90 percent of combat casualties in Sicily required radiographic examination.

TABLE 8.—*Radiologic caseload, 12th General Hospital, January 1943–June 1945* [1, 2]

Area of examination	January–November 1943 (North Africa)	July–October 1944 (Rome)	December 1944–June 1945 (Leghorn)
Head	400	218	248
Sinuses	373	305	542
Mastoids	131	107	53
Facial bones	10	43	95
Mandible	85	60	49
Chest	2,277	1,924	2,526
Ribs and sternum	24	26	46
Abdomen	112	130	64
Shoulder	202	285	261
Stomach and small bowel	697	316	333
Colon	141	70	80
Gallbladder	179	123	117
Pyelograms (intravenous and retrograde)	257	171	193
Miscellaneous	22	6	7
Review outside films	147	50	53
Localization foreign bodies in eye	79	32	47
Pelvis	150	107	156
Hip	102	74	69
Spine	864	600	768
Extremities	2,729	2,879	3,195
Therapy	293	73	28
Total	9,281	7,599	8,930
Outpatient visits	7,978	6,698	7,233
Hospital admissions	10,870	8,838	7,901

[1] The hospital was inactive from December 1943 through June 1944.

[2] During the North African period, the Department of Radiology made three encephalograms and ventriculograms and four myelograms.

2. About 70 percent of priority patients in field hospitals had injuries involving the so-called heavy parts of the body; that is, the skull, chest, abdomen, and pelvis.

3. Unless evacuation hospitals were located far forward, from 70 to 90 percent of their X-ray requests were for views of the extremities.

The annual report of the Medical Section, NATOUSA, for 1943 (*2*) showed that although local variations in the relative frequency of wounding agents were noted in specialized tactical situations, the general ratio was maintained of 80 percent high explosive fragmentation agents (artillery, mortars, bombs, mines) to 20 percent bullets (rifles, revolvers, machineguns). Wounds from aerial bombing were infrequent. Multiple wounds were common; samples showed 1.3 wounds per patient in casualties who reached hospitals alive and 1.8 per patient in casualties dying before admission.

MEETINGS AND CONFERENCES

Radiologists, like other professional personnel, prefer not to operate in a state of isolation, and it was natural that early in the war they should come together to share their experiences and try to find solutions for their problems. Affiliated units established immediate liaison with professional colleagues in surrounding areas, and, just as in civilian life, consultations, conferences, and informal discussions became a regular part of the operations of each X-ray department. The first conferences were held, usually on an informal basis, for case presentations, by hospitals operating in Algiers, Bizerte, Oran, and Tunis. After hospitals had been set up in the Naples area, these conferences became a regular part of the activities of general hospitals. The first such meeting, at the 36th General Hospital in Caserta in December 1943, was attended by 12 radiologists from nearby hospitals. Problem cases were presented, and there was free discussion of technical and other phases of military radiology. Exchange visits to other installations were useful and stimulating but, of course, were possible only during periods of inactivity or while hospitals were in bivouac awaiting relocation.

These meetings and conferences were needed for two reasons:

1. Very few U.S. or British journals of radiology were available in the theater. Even private subscriptions were delivered irregularly.

2. The conferences provided the mechanism for the dissemination of information from one hospital to others and were thus particularly useful in the absence of the current literature.

The whole informal and formal program of professional and scientific exchange culminated in a theaterwide meeting at the 24th General Hospital in Florence on 4–5 April 1945. It was attended by 44 radiologists and 20 other medical, medical administrative (supply or depot), and sanitary officers. The program, which was of unusually high quality and which covered the professional and technical problems encountered during the war, was as follows:

1. Traumatic head cases, presented by Capt. Samuel M. Marcus, MC, 16th Evacuation Hospital, and discussed by Col. Eldridge H. Campbell, Jr., MC, 33d General Hospital, and Lt. Col. Robert M. Crowder, MC, 33d General Hospital.
2. Backache, presented by Lt. Col. Earl R. Crowder, MC, 12th General Hospital.
3. Technical and physical problems of the establishment and maintenance of an X-ray department, presented by Capt. Jack L. Chalek, MC, 26th General Hospital.
4. Supply and training of X-ray personnel, presented by Lt. Col. Earl R. Crowder, MC.
5. Chest injuries, presented by Lt. Col. John M. Dougall, MC, and Maj. (later Lt. Col.) Edward F. Parker, MC, both from the 300th General Hospital.
6. Gastrointestinal studies in theaters of operations, presented by Lt. Col. (later Col.) Charles D. Smith, MC, 45th General Hospital, and Capt. (later Maj.) Henry S. Berkan, MC, 37th General Hospital.
7. The pneumonias, presented by Lt. Col. Abraham J. Levy, MC.
8. Genitourinary injuries, presented by Lt. Col. Leslie F. Wilcox, MC, 17th General Hospital.

In addition to the formal discussions of the presentation on head injuries, there were animated discussions of all of the other presentations, and a number of case reports were presented and discussed.

RECORDS

A major radiologic problem was the lack of medical stenographers. No hospital had a tape recorder, and it was the exceptional X-ray section that had on its roster a typist with any knowledge of medical terminology. Some hospitals were fortunate enough to have among their enlisted personnel men who, in addition to being able to type, had had some scientific or academic training. A few technicians with a knowledge of typing did double duty. Most of the time, however, the policy was for the radiologists, with or without a knowledge of typing, to type their own reports, or to dictate to men who could spell and type. Without any medical background, these men worked with painful slowness, and their reports were not always accurate. Eventually, however, they absorbed some knowledge of radiologic terminology, though with heavy workloads, this method of procedure was a constant source of irritation and often constituted a bottleneck in departmental operations.

The maintenance of accurate records was most important, not only in the patients' interest but also because without them the production of scientific reports would have been impossible.

DISPOSITION OF ROENTGENOGRAMS

The general practice in the Mediterranean theater, as in the European theater, was to forward all roentgenograms with the patients when they were evacuated. The system was not employed uniformly, however, nor was it always well controlled.

In field and evacuation hospitals, which were mobile, the tendency was to keep the patient's roentgenograms attached to his bed, to facilitate their transfer with his other records. If the distance to be evacuated was relatively short, this plan worked well. Over longer distances, films were apt to be lost or damaged when the patient was shifted about or when he was asleep; it was a better plan, especially with seriously ill patients, to collect all records when the patients were evacuated and distribute them when they arrived at their destination.

Even when the policy of moving records with patients was strictly adhered to, circumstances sometimes negated the effort. On New Year's Eve 1943, the 6th and 94th Evacuation Hospitals, located near Teano, Italy, were so battered by heavy winds and torrential rains that large portions of both installations were destroyed. The patients had to be evacuated hurriedly by ambulance to a nearby general hospital. When they arrived their records were incomplete and their roentgenograms had been so damaged by rain and mud that they were practically useless.

Some roentgenograms disappeared, having been taken out of circulation for scientific reasons: The production of scientific papers was a useful and important radiologic activity. Acquisition of data for these papers had to be anticipated, and pirating the roentgenograms was in many respects the simplest way of obtaining them.

For the most part, however, the roentgenograms desired for this purpose were copied. Some officers and technicians possessed excellent cameras, suited for clinical photography, which had been shipped from home, purchased locally, or obtained otherwise, and large numbers of copies of roentgenograms were accumulated, mostly of the 35-mm. type.

The production of clear glossy prints, of a quality acceptable for publication, depended entirely upon the photographic ability of individual radiologists like Sergeant Warren (p. 237) or their technical associates. With the addition of the 35-mm. back with ground glass focusing device, certain cameras such as the Recomar lent themselves admirably to the reproduction of radiographs.

Fine-grain emulsion films, exposure meters, developing tanks, and proper developing solutions were not available within the theater but eventually were secured from the United States. Photographic enlargers suitable for making sharp enlargements proved more difficult to locate. Few were available for purchase, and their bulk made shipping them from the United States impractical. A great deal of thought and attention was devoted to their construction, and eventually, with a pair of tin snippers, a standard No. 10 can, and some ingenuity and patience, an excellent enlarger was devised. Acquisition of a good photographic lens was not too difficult.

A great deal of excellent photographic work was produced from total assemblies of this sort. At the end of the war, many enterprising radiologists returned to their homes with dozens of rolls of excellent negatives showing a wide variety of pathologic states, many of which could not have been observed in a lifetime of civilian practice. Much of this material found its way into the literature and into the teaching files of medical schools in the United States. When the 36th General Hospital was deactivated, it had collected more than 3,500 35-mm. reproductions of roentgenograms taken during its service and had the necessary clinical data to make them usable for future reports and for teaching purposes.

LIAISON

Close liaison was established with British evacuation hospitals which participated in the care of U.S. troops in their areas in North Africa; U.S. hospitals similarly cared for British casualties. During the Italian campaign, U.S. hospitals served troops of many national origins, including soldiers of the famous British Eighth Army, the Canadian-U.S. First Special Service Force, Brazilian troops assigned to the Fifth U.S. Army, and the colorful

troops of the French Colonial Forces, which served during a portion of this campaign. The only radiologic problems that arose concerned the language barrier. The difficulties were solved by the acquisition of a few key words by the technicians, supplemented by the liberal use of sign language.

Station and general hospitals in the Naples and other port areas provided care for naval forces operating in the Mediterranean and made the establishment of separate naval hospitals unnecessary.

When U.S. medical personnel took over Italian hospitals, whether civil or military, the Italian medical staff was usually permitted to continue to care for Italian patients until evacuation could be accomplished. They were assisted, as necessary, by U.S. personnel. On some occasions, good liaison with local civilian radiologists made it possible to procure loans of such items as ionization chambers for radiotherapy dosimetry.

In both Italy and southern France, local physicians availed themselves of the opportunity to observe U.S. techniques, including radiologic techniques. U.S. medical personnel also availed themselves of the opportunity to observe French and Italian techniques. On occasion, unit personnel in various specialties, including radiology, served as consultants to local civilian practitioners in the management of problem cases. All of these measures served to create good will among citizens of occupied areas.

Section II. Personnel

CONSULTANT SERVICE

During the first year of operations in North Africa and Italy, there was no consultant in radiology in the theater, a lack emphasized by the visit, in October 1943, of Colonel Allen. The situation was partly corrected on 5 January 1944 by the appointment of Lt. Col. Earl R. Crowder, MC, as Acting Consultant in Radiology to the theater surgeon, in which position he served until the end of the war (*3*, *4*). Colonel Crowder retained his position as Chief, Department of Radiology, 12th General Hospital, where he was assisted by Capt. Roy F. Dent, Jr., MC. During the period from December 1943 to June 1944, however, when the 12th General Hospital was inactive (p. 244), Colonel Crowder served, in effect, as a full-time consultant. His broad experience and sound clinical judgment fitted him admirably for the duties of a consultant. At the end of his first tour of hospitals, he generously remarked that the high level of proficiency of radiologic personnel made it almost unnecessary for a consultant to supervise professional radiologic operations.

One reason for Colonel Crowder's success as acting consultant was that his approach was refreshingly down to earth. In his opinion, "* * * the practice of roentgenology in this theater of operations has been found to differ, in none of its fundamentals, from the practice of military hospitals in the Zone of the Interior or in civilian hospitals."

Colonel Crowder's opinion was echoed later by Maj. (later Col.) James R. Lingley, MC, 6th General Hospital, who wrote that, since the practice of radiology in an Army general hospital differed little from that experienced in civilian life, radiologists required very little additional training to fit them for Army service.

The tables of organization in effect at the beginning of the war allotted no radiologists to field hospitals; one to 400-bed evacuation hospitals; one to 750-bed evacuation hospitals; two to general hospitals; and one to station hospitals and convalescent hospitals. Colonel Allen's recommendation for auxiliary radiologic teams, which rendered such good service in the European theater, was not, as already noted, carried out in the Mediterranean theater, but professional shortages were sometimes overcome by the appointment on temporary duty of radiologists from hospitals that were staging or were inactive for other reasons. When some thousand-bed general hospitals were expanded, they absorbed the personnel of station hospitals. If, however, their radiologic personnel were sufficient to care for the increased load, the personnel of the station hospitals were assigned elsewhere.

Affiliated hospitals organized through medical schools or large metropolitan hospitals all had Board-certified radiologists as chiefs of service. The second radiologist allowed by the T/O was sometimes Board certified but more often he was not, and sometimes he had had no previous radiologic experience.

Between the invasion of North Africa in November 1942 and the end of the war in Italy on 29 April 1945, 32 Board-certified radiologists served in the hospitals in the theater, 24 in 17 general hospitals, 5 in station hospitals, 2 in evacuation hospitals, and 1 in a 3,000-bed convalescent hospital. Colonel Crowder's figures showed that 25 of the 82 hospitals of all categories in the theater were served by one or more fully trained radiologists. On the other hand, the radiologic officers assigned to 3 (of 7) field hospitals had no radiologic training, and in the remaining 54 hospitals, radiology was done by medical officers trained in the Army School of Roentgenology (p. 30) or with equivalent experience in civilian life.

The staffing of general hospitals with well-qualified radiologists made it practical to send medical officers with less experience, who were serving as chiefs of service in station and evacuation hospitals, to these general hospitals for various periods of additional training. This practice not only increased their diagnostic ability but also provided the stimulation essential to all personnel working in an unfamiliar field. These periods of training were informal in the Mediterranean theater, in contrast to the greater formality with which they were conducted in the European theater.

Utilization of Radiologic Personnel

Most specialists in the Mediterranean theater were correctly utilized, and the highly specialized nature of radiology usually kept radiologists immune to deliberate misuse. In fact, for the reason just stated, radiologic officers

were usually included in advance parties evaluating and planning operations in new hospital locations.

Circumstances, of course, did not always permit the immediate utilization of radiologists in the practice of their specialty. When their units were in bivouac, some of them were utilized in other capacities, as detachment commanders or as general medical officers on transports and cargo carriers in the movements between Africa and Italy, and between Italy and southern France. Many, especially officers in company grade, rode LST's (landing ship, tank), LCI's (landing craft, infantry), and other ships and then were sent ashore and attached to mobile hospitals on the beaches for general duty until their own units were landed and set up.

In isolated instances, radiologists, like other medical personnel, were improperly and illogically assigned. On one occasion, several were detached for duty for periods varying from a day to a week to check military courtesy among combat-weary troops, large numbers of whom had been returned for short leaves from such embattled areas as Anzio. To utilize radiologists and other medical officers to pounce upon enlisted men who failed to salute properly or who were not wearing ties seemed, in the face of the existing patient load, to show an extravagant disregard for the basic mission of the Medical Corps. On another occasion, also in Naples, the commanding general ordered professional medical personnel to patrol the streets as MP officers. This misuse of professional personnel again occurred at a time when all hospital units were operating at full capacity and when the care of casualties should have taken precedence over all other considerations. Fortunately, indiscretions of this kind were infrequent.

Later Certification

During World War II, radiology assumed its proper role as a major medical specialty, and the immediate impact of the military experience was evident in its increasing use after the war. Another important result of the military experience was the stimulation of a number of medical officers who served as radiologists during the war to continue in the specialty and later gain certification in it. Of the 110 medical officers who served in sections of radiology in this theater during the war, 39 were certified before or in the course of the war, and 29 were certified after the war. Many of this latter group had been in general practice or had just completed their internships when they entered the Army. In other words, only 42 of the 110 officers who served in radiology in MTOUSA during the war returned to nonradiologic practice.

TECHNICIANS

Radiologists with previous experience in civilian life knew well the dependence radiologists placed upon their technical assistants. Those in charge of departments in affiliated hospitals anticipated difficulties and fore-

stalled them by enlisting the services of qualified civilian technicians, many of whom had had broad civilian experience as chief technicians in their institutions of origin. This policy contributed to the immediate efficiency of their departments; improved the quality of work done; and also made possible the inservice training of enlisted personnel, which elevated the standards of technical service within their own units and aided other units less fortunate in their technical personnel.

In general, the Army did a remarkable job in its mass production techniques of training in Army schools for enlisted technicians (p. 40). By this plan, they made technical enlisted personnel with at least a basic training in radiologic techniques available for all hospital units. These men did remarkably good work in simple, emergency-type radiography, especially when they served under the guidance of better trained technicians. Sent into the field with no background of technical experience, they worked under difficult conditions, to which they adapted well, and they performed creditably in all hospitals in which radiology was essentially a screening procedure. One reason, perhaps, was that they had been taught to work without the niceties and gadgets better trained technicians considered necessary. Those who proved unadaptable to technical work were assigned to darkroom duties or worked as clerks or assistants to better qualified technicians.

In larger fixed hospitals, in which more precise and more complicated examinations were necessary, Army-trained technicians did not always function efficiently, as might have been expected. The more elaborate technical procedures required for definitive diagnosis in other than traumatic conditions necessitated far greater experience than the Army training school was able to provide.

The T/O allotment of radiology technicians at the beginning of the war was 3 for field hospitals; 3 for 400-bed, and 8 for 750-bed, evacuation hospitals; 20 for general hospitals; 1 to 4 for station hospitals; and 2 for convalescent hospitals. This allotment promptly proved inadequate when mobile hospitals went into operation in North Africa. In fact, when these hospitals were under extreme pressure, double T/O strength was necessary to approach a point of adequacy. Auxiliary radiologic teams would have been most helpful at such times.

Training

Newly organized hospitals often arrived in the theater staffed with Army-trained officers and technicians who had had no practical experience. Whenever it was possible, before these hospitals became operational, the ranking noncommissioned officer and the radiologist in charge of the service were sent to well-organized general hospitals for a period of orientation. Such inservice activities proved extremely helpful. Indeed, the capacity of these technicians to absorb information on procedures, techniques, and improvisations to augment their basic equipment was sometimes almost incredible.

In many fixed installations with well-qualified technicians, formal courses of training were set up for the hastily trained technicians assigned to them. The fundamentals of physics and of radiographic exposures were presented, as well as demonstrations and discussions of standard positioning.

These plans worked very well. Another had to be abandoned: When lulls at the front permitted, technicians were sent on detached service to general hospitals in the rear, for periods up to a month. During this time, they were integrated into the departmental routine and were given individual instruction. It was decided that the difficulties under which technicians in forward hospitals worked, rather than their lack of appreciation of fine technical points, were responsible for the poor quality of many of their radiographs. Also, as so often happens, exposure of these technicians to better working conditions and to the pleasanter atmosphere of general hospitals made them dissatisfied with their own more primitive forward facilities.

As the end of the war approached, some Army-trained technicians who had developed an interest in their work expressed the desire to continue in it on their return to civilian life. The work routine of Army radiology departments, especially of forward hospitals, was far removed from that of civilian hospitals, and even civilian-trained technicians had developed some working habits which needed readjustment. The examination of patients when landmarks would have to be determined under drapes, the complex specialized examinations, and the special views required in civilian practice pointed to the need for refresher courses. Also, technicians who had worked only with field X-ray units required training in the more elaborate equipment which many hospitals had received by this time.

A number of general hospitals therefore set up series of lectures and demonstrations designed to prepare technicians for their return to civilian employment. Wherever these courses were instituted, they evoked keen interest. Departmental personnel attended faithfully, as did technicians from nearby hospital units, and young radiologists who had developed an interest in the specialty found much to learn from experienced technicians concerning techniques.

Grade

Another deficiency of the tables of organization was the limited ratings for technicians, the highest being T/4, which was not adequate for the high degree of skill and responsibility required of chief technicians. In some hospitals it was possible to manipulate assignments to provide ratings commensurate with the ability of well-trained technicians. One of Colonel Crowder's recommendations was that a technical sergeant be allowed for each 750-bed evacuation hospital, and a technician, third class, for each 400-bed evacuation hospital and each 3,000-bed convalescent hospital.

MORALE

Morale is seldom a problem when men are busy. In North Africa and Italy there was little opportunity for boredom to creep into the operations of most X-ray departments, which worked at full capacity, and often beyond it, during most of the war.

Periods of relative inactivity were usually associated with preparations for movement of the hospital. In general, such periods were used to replenish supplies, care for equipment, and arrange to move to the new location. What time was left was spent in well-earned rest. Some radiologic personnel tried to use these times for improvement of their technique by visits to other units.

As the war progressed, staging periods were used to compile data, reproduce radiographs, and prepare clinical reports.

On the whole, except when radiologists were used in the wasteful and unorthodox manner previously described, morale was not a problem among radiologic personnel in the Mediterranean theater.

OTHER PERSONNEL

Supply.—Affiliated units, in addition to their foresight in securing experienced technicians, were frequently able to add experienced supply personnel to their staffs. Men with a background in the medical supply section of a large civilian hospital could make the operation of the X-ray department of a military hospital much smoother. They were trained to maintain adequate stocks, and they appreciated, as inexperienced supply personnel did not, when immediate action was necessary to obtain the key items without which an X-ray department cannot operate.

Litter bearers.—The transportation of patients to and from the X-ray department was often a major problem, which created serious bottlenecks when the casualty load was heavy and when hospital personnel were augmented by auxiliary surgical group teams. All seriously ill casualties had to be transported, and so did all wounded put up in casts, splints, and other orthopedic devices.

In some hospitals, hauls of up to two city blocks were not unusual. Wheeled litters were seldom available, and they sometimes stuck in the mud when they were. Ambulances, weapons carriers, and other vehicles were used when available, but they were never allotted directly to an X-ray section, and their availability could not be counted on. Although several of the newer and more modern civilian hospitals taken over by the U.S. Army had elevator service, it was never entirely reliable. In older hospitals, such as the Ospedale Militare in Caserta, there were no elevators, and patients had to be carried up and down stairs that frequently were narrow and twisting.

The number of litter bearers permitted by the T/O was never sufficient. Many of those assigned to the task were incorrigibles, who did not fit into other categories and who required considerable supervision. Prisoners of war

were often pressed into service. Conservation of manpower was practiced whenever possible by such devices as placing ambulatory patients on the upper floors and litter patients on the ground floors, or placing ambulatory patients in the more remote wards. The problem of personnel for litter transportation was never really solved, and the bottlenecks caused by it continued until the end of the war.

Civilians.—The technical staff could sometimes be augmented by using civilians—and Italian military personnel—in occupied areas. When the 36th General Hospital moved into the Ospedale Militare in Caserta, it found an extremely competent Italian Army technician on duty. Regulations would not permit his use in that capacity, so he simply removed his uniform, joined the staff as a civilian, and rendered highly effective service as an integral part of the X-ray section.

Most hospitals employed local civilians. Their radiographic competence varied, but they were useful because of their knowledge of local customs and local sources of supply. It was often possible, through them, to procure locally items not obtainable through regular supply channels.

U.S. Army radiologists working in requisitioned Italian hospitals were happy to encounter the familiar headdress of Sisters of Charity and other orders. The nuns were cheerful hard workers; their knowledge permitted the use of many items of Italian equipment which otherwise might not have been utilized.

Section III. Facilities and Equipment

HOUSING

Field and evacuation hospitals that had to become operational as soon as possible after assault landings were all amply provided with canvas and could be set up promptly. Diagnostic roentgenology could be carried out in these circumstances, but the peculiar requirements of this specialty made more permanent locations desirable as rapidly as possible.

Permanent buildings used for hospitals in the Mediterranean theater included military (fig. 69) and civilian hospitals, schools, barracks, stables, and even indoor riding rings with cement floors laid over the tanbark. One such ring was converted to a 250-bed orthopedic ward, which required the services of two X-ray crews with mobile units practically full time. One of the desirable features of permanent buildings was the existence of sewage facilities and a water supply.

It was always operationally important in forward hospitals that the X-ray department be located close to the operating room, since practically all casualties who underwent surgery first required X-ray examination. A hospital commander, who had once experienced the bottleneck that could result from the poor location of an X-ray department and the inadequate allotment

FIGURE 69.—Ospedale Militare, Caserta, Italy, taken over by 36th General Hospital. A. Hospital with king's palace in background. B. Enlisted men's barracks with hospital in background.

of space to it, was much more amenable to the proper housing and location of this department when his hospital moved again. When station and general hospitals moved into existing hospital facilities, whether military or civilian, the X-ray department was usually found to be located already in general proximity to the operating room. In larger fixed institutions, the nearer the X-ray department was to the wards, the fewer were the difficulties associated with the transportation of patients (p. 253).

The operational problems encountered by the 12th General Hospital in Oran in December 1942 were of physical origin. It occupied 105 buildings, chiefly villas, in an area 300 feet deep and ¾ mile long, on three levels along the long axis. The first level was 150 feet above the sea, the second 50 feet higher, and the third 100 feet above the second. The difference in levels, with the necessity for entering each one by a stairway from the street, made the

transportation of patients extremely difficult. The dining facilities were placed on the third level, and hospital personnel, especially litter bearers, needed no other exercise.

Many of the buildings taken over by the Army in the Mediterranean theater were in poor condition, and X-ray technicians were always eager to improve their status. The only paint available in abundance was the green paint used for camouflage, and many interiors were improved by its use. The X-ray department of the Ospedale Militare in Caserta was quite adequate except for the dingy appearance of its original white paint, and it took considerable persuasion before the commanding officer of the hospital agreed to have the supply section release a quart of white enamel, which, by ways known only to X-ray technicians, was eventually stretched into 5 gallons.

Assignment of Space

The X-ray department in a military hospital required more space to work adequately than would be necessary in a department whose patients were predominantly ambulatory. This is a very important point, still frequently overlooked. Seriously wounded patients put up in complicated splints and other orthopedic devices could not be handled in a small space. Departments doing emergency examinations of heavy body areas also required adequate space; in complicated cases, it was frequently necessary to use both the mobile unit and the fixed table unit to obtain the required projections.

Darkroom.—When hospitals were under canvas, two tents, and sometimes three, were often required to permit the simultaneous processing of films and fluoroscopy with radiography. Adequate darkroom space was essential because of the large volumes of work that had to be handled expeditiously (fig. 70). Also, supplemental facilities for washing films were frequently required, and the inadequate capacity of the driers required the use of improvised drying equipment.

Toilet facilities.—The need for handy toilet facilities in X-ray departments doing examinations of the colon by barium enema was critical and immediate. A memory common to most X-ray personnel concerns a harried patient running down a narrow corridor, clutching a Bardex enema tip and finding the single toilet already occupied.

PROTECTION

In the light of the current (1965) emphasis on protection from radiation, it is interesting to speculate on the amount of exposure received by X-ray personnel during the operation of a busy hospital section in World War II. The conjectures might also include what the effect would have been on the functioning of the department if rigorous supervision and measurement of exposure had then been required. Conscientious radiologists were aware of

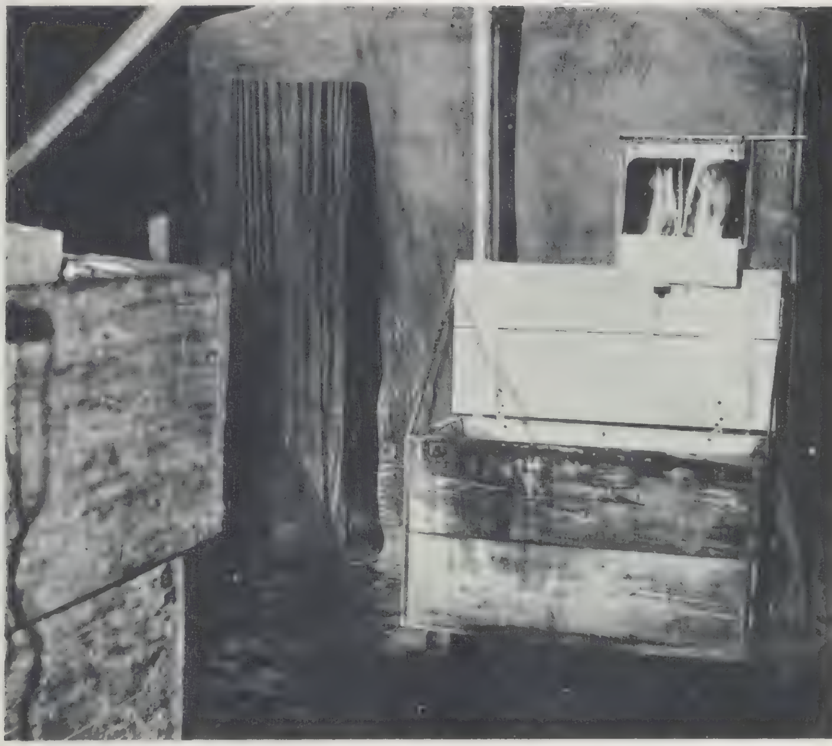


FIGURE 70.—Darkroom in tent, 8th Evacuation Hospital, Teano Area, Italy, showing difficulties of operations in field.

radiation hazards and did all that was possible with the materials at hand, but no monitoring equipment was available, and only rough estimates of dosage could be obtained by using the old-fashioned technique of dental films with attached paper clips, supplemented by routine blood counts. There is little doubt that the postwar standards of maximum permissible dose were far exceeded at certain times during the war. Protective measures, however, were comparable to those employed in many civilian hospitals at the time, and no immediate serious consequences of exposure were observed. Radiologists who were in service in World War II have apparently not observed many sequelae of exposure since the war.

Mobile units operating in the field under canvas faced the most serious problems in providing protection against radiation, since there were no solid structural walls to provide any type of barrier (fig. 71). In these circumstances, distance offered the only real safety potential. When hospitals operated in permanent buildings, it was often possible so to locate the X-ray department that heavy walls could be used to divide rooms and separate control panels.

The basic problem in respect to protection of X-ray personnel was the

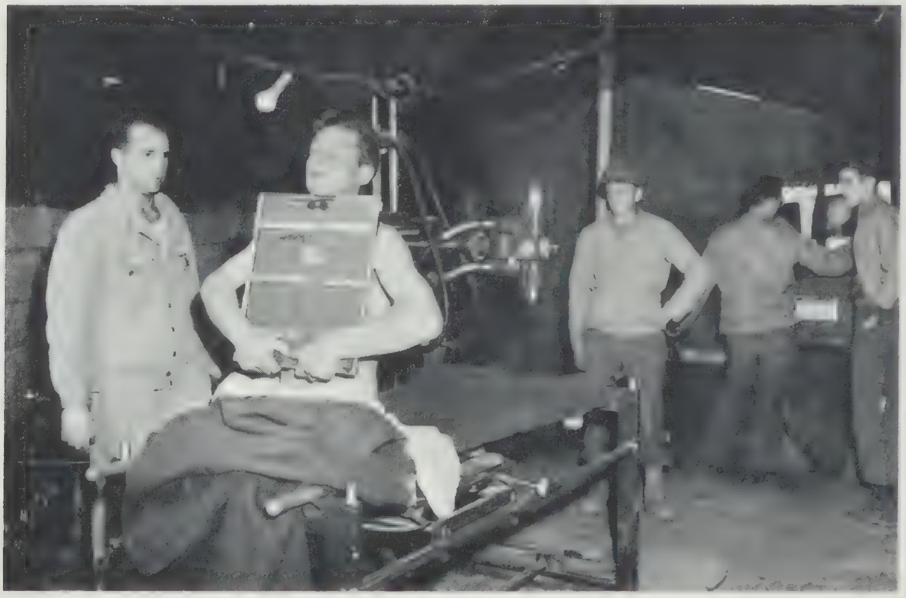


FIGURE 71.—Field operation of X-ray section, 15th Evacuation Hospital, Anzio, showing inadequate radiation protection.

limited amount of sheet lead supplied for even large general hospitals. The usual allotment was one roll, $\frac{1}{16}$ of an inch thick, 3 feet wide, and 14 feet long. At best, this amount was enough to construct protected control booths for only two units. There were additional complications: Very often even this limited amount of lead failed to arrive with the other hospital supplies, a situation readily explained by anyone who ever observed the handling of hospital supplies on a beachhead or even during planned and well-regulated transshipments. The lead roll, being a small, compact bundle, frequently attracted the attention of detachment personnel seeking something to carry that was not very large. The expression on the faces of these men when they picked up the compact little bundle was usually one of shocked surprise. The end result was usually the same; the lead was almost always the last item to leave the beachhead or depot, and rather often it became a permanent feature of the terrain. Protective lead sheeting was therefore one of the most sought-after items obtained from civilian sources by barter or by what was known as moonlight requisition (p. 267).

Lead rubber was supplied in only small amounts. It was all used in the construction of dividers or masks for radiography and for field demarcation for radiotherapy.

Lead glass was not included in T/E's (tables of equipment) and was practically unobtainable except for fragments procured when a protective fluoroscopic screen was broken. Sometimes, when all field tables were not in

use for fluoroscopy, the screen was removed and its lead glass diverted to other uses.

Lead aprons and gloves were of good quality but were not provided in sufficient quantity for use at all times by radiologists and technicians. The shortages were particularly felt in the use of mobile units on the wards, which in some hospitals amounted to almost a full-time operation. It must be added that many X-ray personnel, finding the aprons hot, cumbersome, and in their way during their duties, simply failed to use them.

Capt. (later Maj.) Sidney M. Silverstone, MC, Chief of Radiology, 3d General Hospital, summarized his own experience in protection against radiation as follows:

> * * * one of the major problems we had with each of our hospital setups was protection of the personnel who were taking films. When we were stationed in North Africa at Mateur (30 May 1943–4 May 1944), we found some sheet lead in an Army depot and we were able thereby to construct several protective booths. We had similar problems in Italy and southern France, but in each instance we were able to locate some lead and build protective enclosures. The mobile x-ray diagnostic unit worked very well but there was not the protection provided for the technician. A lead apron was not adequate.* * * Routine blood counts were taken regularly every month on every technician. In a few cases it was necessary to transfer some of these men to other departments because of leukopenia.

POWER

For proper functioning, an X-ray unit had to have adequate electric current. Motor-driven field generators of the 1.5-kw. type were designed to serve one field unit, which had to deliver 30 ma. at 85 kvp. with a load drop not to exceed 5 kvp. The generators supplied usually proved adequate for individual field units, but they were not designed to meet the needs of a general hospital with a large workload.

It might be added that these generators were noisy to the point of distraction, and their exhaust fumes were both irritating and potentially dangerous when the machines were set up close to the X-ray tents. When, to quiet the noise and eliminate the fumes, they were removed a reasonable distance from the department, the line drop seriously affected the operation of the equipment.

In a survey of X-ray departments in forward hospitals in the theater in March 1945, Colonel Crowder found that three types of generator equipment were in use:

1. The 3-phase, 30-kw., diesel-driven generator, which provided a good source of power for X-ray machines when the load on the three phases was properly balanced.

2. The 3-phase, 15-kw., diesel-driven generator, which was also a satisfactory source of X-ray power when it was not fully loaded. The same phase loading had to be observed as with 30-kw. generators.

3. The single-phase, 5-kw., gasoline-driven generator, which was not a

good source of X-ray power because its voltage output was unstable when it was carrying additional loads.

Colonel Crowder recommended that the following generator capacity be provided:

1. For each 300-bed field hospital, six 15-kw. or nine 5-kw. generators.
2. For each 400-bed evacuation hospital, two 30-kw. generators.
3. For each 750-bed evacuation hospital, three 30-kw. generators.
4. For each 3,000-bed convalescent hospital, two 30-kw. or two 15-kw. generators.

Electrical conductors of adequate size were hard to find. The No. 4 wire specified in the T/E was unable to carry the load of several X-ray units on which simultaneous exposures were being made. The fundamental requirement was that the powerline be direct from the generator panel to the X-ray machine and that the wire size be sufficient to limit the voltage drop at the machine to 2½ volts. No load other than that of the X-ray machine should ever have been placed on this line, but this rule was not obeyed. When transit distance and load combined to make the No. 4 wire of insufficient capacity, it was occasionally possible to obtain larger sizes. Moonlight requisitioning, although officially condemned, could be depended upon to provide No. 0 and No. 00 cable, which could be quickly installed by radiologic personnel.

When a proper source of current was at hand, with large conductors carrying the power to the X-ray units, and an unstable line still persisted, balancing the load on the three phases of the generators usually produced proper distribution and rectified the difficulty. Some hospitals solved the power supply problem by rewiring the controls of the field units, so that 208 volts could be used instead of the usual 110 units. These difficulties paralleled those experienced in the European theater.

Some difficulties were created by the unfamiliarity of engineers with the electrical needs of an X-ray section. Thus central power units were not always properly located. In one general hospital, a bank of diesel generators was set up a quarter of a mile from the X-ray department, and current was sent to the equipment through No. 14 wires. Relocation of one of the generators, which was placed immediately outside the department, solved that special problem immediately.

In only a few hospitals in North Africa did Colonel Crowder find sufficient power, even for 30-ma. X-ray units, and the man responsible for it, 1st Lt. Charles S. Barron, CE, had been moved, no one knew where. Later quite by chance, Colonel Crowder encountered Lieutenant Barron at the 32d General Hospital, where he was undergoing treatment for severe arthritis, severe enough, in fact, to warrant his return to the United States. Lieutenant Barron, however, wished to continue his work in the theater, and arrangements were made to board him because of his arthritis, put him on limited service, and assign him to medical administration. As Acting Consultant in Radiology, Colonel Crowder circulated very rapidly, and somehow he always knew how to reach Lieutenant Barron when there was trouble with the power supply.

Lieutenant Barron was an outstandingly capable engineer, and in addition to his assistance when difficulties arose with current, he was able to put a good deal of equipment back into service (*5*).

In Algiers, Colonel Crowder was able to obtain the assistance of the engineers in the local power company and received a great deal of help from them.

EQUIPMENT

Picker Field Unit

The Picker field unit (p. 62) was the standard radiographic unit for all installations, and within its limitations it was an excellent piece of equipment. It operated satisfactorily on gasoline-motor-driven 1.5-kw. generators when no additional load was placed on them. High voltage cables were interchangeable between anode and cathode terminals of the X-ray tube. The tube itself was air cooled, lightweight, and withstood usage extremely well. The unit was readily transportable and was easily and quickly assembled. One of its advantages was that it permitted operation independent of a central power supply.

This equipment served well in field and evacuation hospitals, though even in them it presented a number of operational problems. One was that the small, hard rubber casters made it difficult to move the unit on dirt floors. These difficulties persisted to some extent even with the later models, which were provided with larger wheels and pneumatic tires. Many evacuation hospitals constructed sectional, transportable wooden floors to solve this special problem.

Army technicians had the greatest respect for the Picker field unit when it was used within its capabilities. It was, however, a low capacity unit. It was well suited to basic, screening type procedures, but it was primitive and inadequate for fixed hospitals that had to provide a complete diagnostic service. Its low capacity required long exposures. The total assembly was lacking in flexibility. Long focal-film distances were required for desirably sharp detail. Finally, this machine lacked the accessories vital for radiography of really high quality (fig. 72).

The incorporation of the foreign body localizing apparatus in the field unit (p. 72) was probably the greatest single impediment to the competent operation of the unit. The lack of a Bucky diaphragm was probably the greatest single unmet radiologic need. Without a Bucky, adequate radiographs of the heavy parts of the body were not satisfactory. The grid provided was useful but could not compare in efficiency with the moving type. The lack of a tabletop made it imperative to secure one locally or to improvise one; radiography without it was extremely difficult.

All units in the field and all fixed installations at one time or another obtained items of equipment not included in the standard T/E. Some equip-

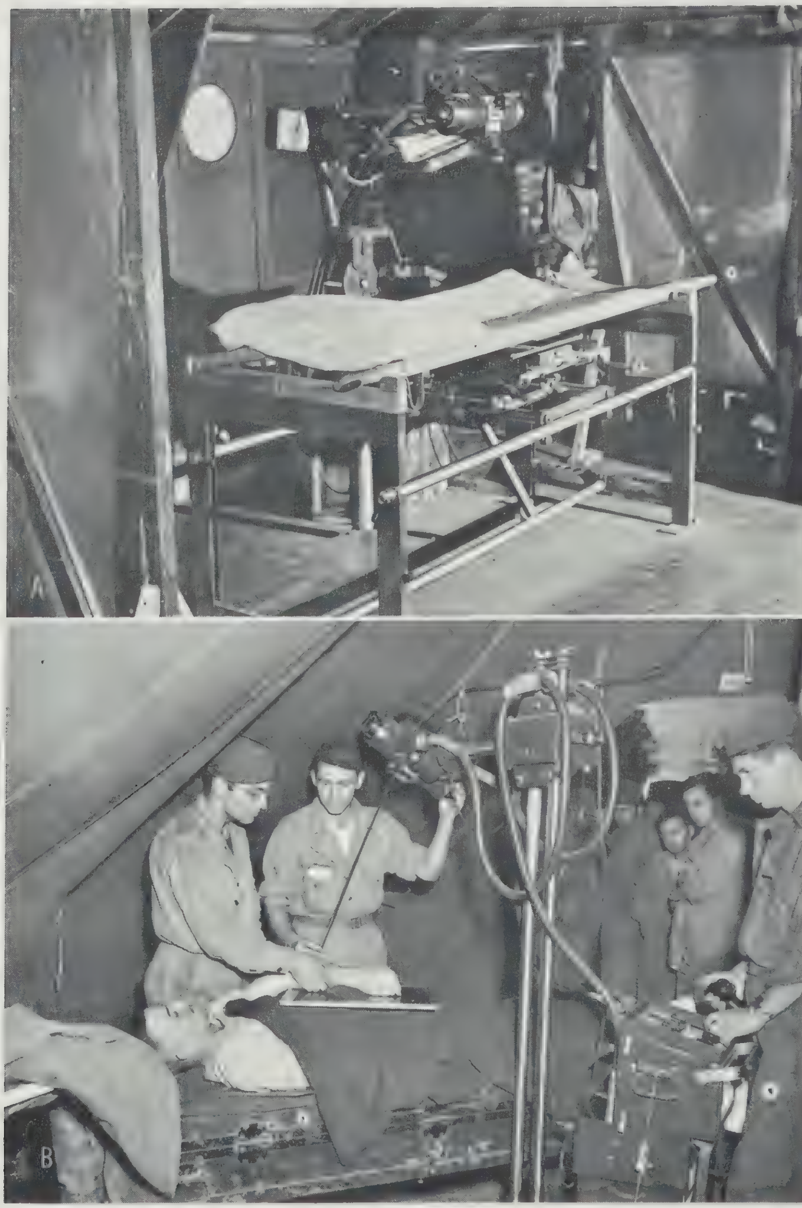


FIGURE 72.—Standard table and Picker field unit. A. Unit without tabletop, coning, and Bucky diaphragm, 8th Evacuation Hospital. Note fixed tube film distance and lack of flexibility. B. Mobile Picker unit, 95th Evacuation Hospital, Capua Sector, showing improvised table (field table truck).

FIGURE 73.—Liberated Bucky diaphragm attached to cassette changer and used for vertical pneumoencephalography, 36th General Hospital, Caserta, Italy.

ment was secured when foreign civilian or military hospitals fell into U.S. Army hands (fig. 73). Others were obtained by moonlight requisition already mentioned, or by quiet barter between units. Technicians from evacuation hospitals, for instance, having no need for all the radiographic field equipment provided, might trade the unwanted items for additional wash tanks, brought from general hospitals in the rear, which they needed badly. The system was considered justified, for the additional equipment thus acquired greatly improved the quality of technical and professional radiologic performance.

The relative cost of the items exchanged was inconsequential. A stationary grid, for instance, might well be considered the equivalent of a complete Army field unit plus a hammer, a saw, and a pair of pliers. Few transactions of this kind were officially reported, but many were arranged, and the traders were well satisfied with the exchange.

Other Equipment

The equipment supplied for the darkroom of the X-ray department was of reasonably good quality and adequate for basic needs, but there were numerous deficiencies. The motors in the cooling units were subject to frequent breakdowns. The plumbing fittings on the wash tanks were of such poor quality that they deteriorated after they had been connected and disconnected several times, and they soon became unserviceable. Then the tanks had

FIGURE 74.—Darkroom, 8th Evacuation Hospital, Teano Area, Italy. Note combination unit film-loader and drier with adequate supply of hangers.

either to be replaced or to be fitted with hoses. The film drier was of poor quality and of totally inadequate capacity under almost all operating circumstances. Provision for loading cassettes and films was satisfactory, but it did not compensate for the lack of a good pass box (fig. 74).

Fluoroscopic Equipment

Fluoroscopy was possible, to some degree, in the horizontal position, but there was no provision for vertical fluoroscopy, which was an absolute necessity, especially in fixed installations. There was also no provision for spot films during fluoroscopy, a procedure that almost all experienced radiologists depend upon for accurate diagnosis.

No cones or extension cylinders were provided, and radiographic detail suffered considerably until this equipment was furnished or improvised.

Liberated Equipment

As time passed, excellent foreign 200-ma. X-ray units found their way into a number of large fixed hospitals. They were equipped for fluoroscopy

and radiography. Several of the Italian hospitals acquired by U.S. Army units were also well supplied with both diagnostic and therapeutic equipment.

Complications sometimes developed when hospitals moved and foreign units, which were not standard issue, had to be transshipped. The solution was not always to the credit of those responsible for the decisions. On one occasion, when a large general hospital had occupied one site for 9 months, it was able to utilize a vertical Siemens unit, equipped for fluoroscopy and horizontal radiography. When the hospital was to move and the building was designated for nonhospital use, attempts were made to dismantle, crate, and ship this equipment with the standard issue X-ray unit. In spite of the great value of this equipment and its part in the improved performance of the department, instructions were received to leave it in situ. When the building was cleared for its future command function, this fine equipment was pushed over a 6-foot platform into a mass of debris and totally destroyed.

Another piece of equipment was saved from such a fate. It was found in a liberated hospital and consisted of a new 200-ma. Siemens unit, complete with rotating anode tube, tilt table, and fluoroscopic assembly (fig. 75). As soon as it was put into use, the quality of the work of the department promptly improved.

When the general hospital that had been using it was suddenly moved to a more forward area, a group of technicians were left behind to salvage what they could during the night. The heavy transformer for this unit was mounted in a room below the table, the only access to which was via a small circular staircase of insufficient width to permit the removal of the transformer. The technicians solved that problem by chopping a 4-foot hole in the floor, elevating the transformer, and transferring it to the waiting weapons carrier on which the table and controls had already been placed. By daybreak, the group had put a hundred miles behind them. The gaping hole in the floor of the stripped radiographic room that greeted the incoming unit brought righteous screams of anguish heard far up the chain of command.

Losses and Breakage

Losses and breakage during transportation accounted for about 15 percent attrition of equipment. When the 26th General Hospital was sent to Bari, Italy, on assignment to the XII Air Force Service Command, to operate the Ospedale Militare Lorenzo Bonomo, the waves were so high that the ships could not be unloaded. Bari was near a major air center, and enemy bombing resulted in an initial loss of all hospital equipment and supplies because of direct hits on the supply ships, all of which were sunk. One of these ships carried chemical warfare agents, and the mustard gas that escaped was responsible for a large number of casualties, including 75 fatalities. The 26th General Hospital established a small emergency hospital and operated at Bari for about a month, using Italian equipment until its own lost equipment, including X-ray equipment, was replaced.

FIGURE 75.—Maj. James E. Lofstrom, MC, before fluoroscopic screen and spot film device on liberated Siemens 200-ma. unit, 36th General Hospital, Caserta, Italy.

Breakage was always greater when transshipment was necessary after an initial period of operation, packing in the field being much less protective than the packing of new equipment by the manufacturer.

A certain amount of loss and breakage was almost unavoidable in the landing operations carried out in the Mediterranean theater, all of which were urgent. Ships were unloaded along beaches that had no port facilities. Haste led to careless handling. Some crates were dropped into the water. Those that reached the beaches intact were always in danger of being crushed by the landing ramps of LST's unless they were quickly moved from the water's edge. It was frustrating to stand by and watch an LST lower its loading ramp with a crunch on top of crates which thereupon spewed essential equipment, including X-ray equipment, into the water.

The vast quantities of supplies unloaded from a single ship, and the fever pitch at which men worked during the hours after a landing, for fear of enemy bombing and shelling, almost precluded the orderly segregation and distribution of the supplies. Crates and boxes were scattered up and down the beaches and were often hauled away without proper identification. Some hospital X-ray units thus lost a major portion of their equipment and were unable to function until it was replaced. Others, as at Bari, lost all of their equipment when the ships carrying it were sunk. Practically every unit suffered some loss and breakage.

MAINTENANCE AND REPAIR

The lack of simple tool kits was keenly felt by all X-ray departments from the beginning of operations, since it was necessary for departmental personnel to modify or construct benches, tables, pass boxes, and other items of equipment. After a few such experiences in setting up for operations without the basic tools needed for elementary carpentry, most X-ray departments acquired what they needed from other departments of the hospital or from other hospitals by either barter or moonlight requisition.

The training that technicians received at Army schools gave them a reasonably good foundation for first echelon maintenance of equipment in hospitals. This was fortunate, for repairs were frequently required, their number being proportional to the degree of hospital mobility. Hospital units fortunate enough to have competent engineering personnel in their roster, or X-ray technicians with a civilian background, were lucky. The number of repairs necessary increased as time passed. During the first year of operation, when the equipment was new and hospitals were not always active, the need for repairs was considerably less than it became later. When fixed hospitals moved forward with the advance of the frontlines, their equipment also began to need repair.

One of the odd aspects of replacement of damaged parts of the field unit in the Mediterranean theater was that when anything went wrong, the entire unit had to be replaced. Thus, if a piece of lead glass was broken on the fluoroscopic equipment attached to the field unit, the entire table unit had to be returned to the supply depot for replacement. This was a cumbersome and time-consuming method of repair; the only advantage to it was that the depots usually had equipment that could be salvaged and used for parts for other equipment.

One of Colonel Crowder's recommendations was that a supply officer, with proper qualifications, be attached to the medical depot (*3*). His functions would be to travel among the various depots to organize repair services in them; to instruct repairmen and aid them in their technical problems; to advise depot commanders concerning the kinds and amounts of spare parts that should be maintained; and to serve as liaison with ordnance, engineer, and signal corps units, whose skills and materials were often necessary for the

adequate operation of X-ray equipment and its servicing. Army-trained technicians had not had enough experience with the more complicated equipment available in some of these units, and they promptly ran into difficulties when repairs of any complexity were required.

The valuable services of Lieutenant Barron have already been mentioned (p. 260). When he investigated the large amount of unserviceable equipment in the Naples depot, designated for return to the Zone of Interior, he was able to put some 70 percent of it back into commission. A Mattern control, for instance, had been dropped on end and was regarded as totally destroyed. Lieutenant Barron took it entirely apart and restored it to useful operation.

One of the more challenging types of service required of maintenance men was the installation of liberated equipment, such as the Siemens 200-ma. radiographic-fluoroscopic unit at the 36th General Hospital in Caserta. All the wiring diagrams were in German, and few if any of the German POW's (prisoners of war) understood the technical terminology. Attempts to decipher the diagrams were frustrating in the extreme (fig. 76). The unit was finally set up by an engineer who was located in a not-too-distant medical depot and who had formerly worked for one of the major X-ray companies in the United States.

IMPROVISATIONS

The inadequacies of the table of equipment for X-ray departments are best appreciated by reviewing the improvisations devised to supplement it. Personnel in hospitals that came into the theater in later stages of operations, when more powerful X-ray units and other equipment not originally supplied were available, can have little comprehension of the problems that faced the hospitals that were in the theater in the first months of combat.

Most of the improvisations devised in the theater were constructed by X-ray personnel, often with the assistance of ordnance and engineering companies in the vicinity. Without junk piles and supply dumps to draw upon, the quality of radiographs in every hospital, regardless of its size and mission, would have been far poorer than it was.

Wood was the item most readily obtained, and practically every X-ray department constructed some sort of tabletop to provide a flat, solid work surface. The devices used ran the gamut from crude platforms or doors to the beautifully polished mahogany plywood tabletops constructed in Italy (which also made excellent Ping-pong tables).

Pass boxes, darkroom workbenches, drying devices, and control booths were fairly simple to make. Other accessories offered more of a challenge to the ingenuity of the U.S. soldier and radiologist. As in the European theater (p. 379), they included spot-film devices, laminographs, operating room fluoroscopes, pneumoencephalographic chairs, and cones and extension cylinders. Cones and cylinders were constructed from shell casings (fig. 77) and served their purposes well, though they were somewhat heavier than those

FIGURE 76.—Many heads pondering directions in German for wiring of liberated Siemens unit, 36th General Hospital, Caserta, Italy.

currently available commercially. Some units fabricated good workable kymographs by reversing the customary types of construction and using a fixed grid surface, with the cassette moving behind it.

The history of the 6th General Hospital (*6*) mentions the following improvised equipment:

1. A spot-film device constructed by the 98th Ordnance Company from plans prepared by Capt. (later Maj.) Stanley M. Wyman, MC. Used as an attachment to the 200-ma. machine, it permitted the fluoroscopist to record instantly anything which he observed on the screen during the examination and wished to preserve. It was used to record the position of metallic foreign bodies in relation to internal organs and was of special value in gastrointestinal work. In these studies, it provided a detailed examination of unusual patterns of the stomach and intestines. The permanent record of the size and the contours of any lesions detected added to the accuracy of diagnosis and permitted an efficient check of the results of therapy.

2. An operating room fluoroscope constructed from a model developed by Maj. Henry Carney, MC, of the 152d Station Hospital and modified several times. The standard Army field table and machine were used, with the tube in position over the table. Under the table was a light-tight plywood box constructed around the rods from the tube stand. The top of the box was formed of a fluoroscopic screen with overlying fluoroscopic screen grid. A mirror in the bottom of the box was placed at such an angle that any image

Figure 77.—Extension cylinder, heavy but efficient, constructed from shell casings and attached to Picker field unit. Note also mahogany plywood tabletop. 36th General Hospital, Caserta, Italy.

on the fluoroscopic screen was reflected laterally out through a plywood extension of the box to the tube column side of the table, where the fluoroscopist sat. A cloth hood, under which he placed his head, enclosed the aperture to the plywood box and excluded light.

When this device was used, the patient lay on the operating table in the position designated by the surgeon. Whenever the surgeon wished to know the relation of his instruments to the foreign body he was seeking, he placed a marker in situ in the wound and stepped back from the table while the fluoroscopist removed his goggles; placed his head under the hood of the viewing aperture; depressed the foot switch; and observed the foreign body and marker, which were projected on the screen and reflected to him by the mirror.

By the end of June 1944, this method had been used successfully in 10

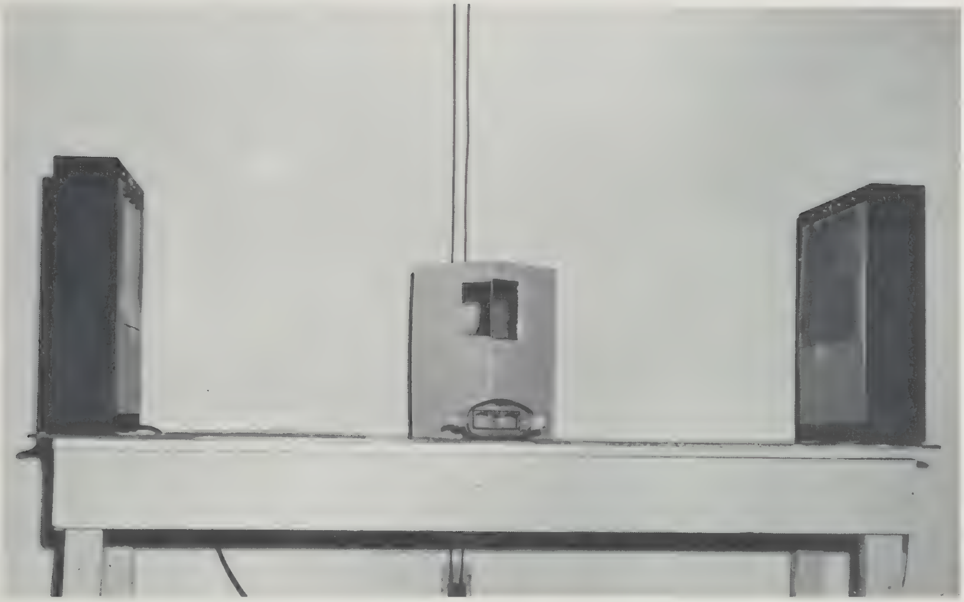


FIGURE 78.—Stereoscopic viewing device constructed at 73d Station Hospital, Rome.

reported cases. It permitted small incisions with rapid identification of the fragment and thus avoided extensive dissections and trauma. It was of little value, however, in the identification of foreign bodies less than 5 mm. in diameter and obscured by overlying bone, and it could not, of course, be used when volatile anesthetics were used, because of the proximity of the X-ray machine.

3. A laminograph, constructed by making the radiographic tube move in one direction during the exposure while the film beneath the patient moved in the other. The tube and film tray were connected by a rod pivoted near the table. On the radiograph, only those body structures were visible that lay at the pivoted point between the tube and the film. This point could be varied at will, so that it was possible to radiograph any selected plane of the body by setting the point to correspond to the desired depth. The fittings for this apparatus were constructed by the 98th Ordnance Company and fitted to the 200-ma. X-ray machine.

Stereoscopic devices.—Stereoscopic viewing devices were not included in the tables of equipment, and most radiologists working in the field were satisfied to do without them. In at least one instance, however, at the 73d Station Hospital, the radiologist felt compelled to have such equipment and devised a stereoscopic viewing table which he put to good use (fig. 78).

Bucky diaphragm.—With all their ingenuity, the improvisation of a Bucky diaphragm proved beyond the capacity of radiologic personnel or their assistants in other services. In most hospitals, the best that could be done was

to remove the low ratio Bucky furnished with the urologic table and mount it on the standard radiographic table. In some hospitals, supporting brackets were machine-made, so that the diaphragm could be used interchangeably.

In some medical depots there was an excess of urologic tables, and, at Colonel Crowder's suggestion, the Bucky diaphragms attached to them were requisitioned. These requisitions were consistently refused or ignored in the Oran Supply Depot. Rumor had it, however, and probably correctly, that some of the diaphragms did find their way into theater X-ray departments.

Whatever the technique by which it was secured, the addition of a Bucky diaphragm to the standard X-ray table, topped by a solid surface, immediately produced a marked improvement in the quality of radiographs.

The comforts of home.—Although improvisations carried out by radiologic personnel usually were for the benefit of the departmental professional and technical performance, certain of them made life in the Army more comfortable than it might otherwise have been. When a hospital moved into a new area, there was general scrounging for useful articles, and bathtubs ranked high on the priority list. Scouts from X-ray departments were particularly successful in such forays, since their movements were likely to be interpreted as being under the command of their own officers and noncommissioned officers. In one fixed installation, a squad of eight X-ray technicians entered the building allocated for officers' quarters, openly lifted the bathtub from its bed, and carried it through the assembling officers across the court to the X-ray department. Next day, engineers arrived with power hammers, rammed holes in the corridor walls, and ran hot water lines, suddenly important to the operation of the darkroom, through the department. Good rapport among GI's made it quite natural that a stub should be connected to the purloined tub directly across the hall from the processing room. It need scarcely be said that the morale of the X-ray department was high during this entire operation and that key enlisted personnel from other departments who were permitted to use this priceless facility were happy to cooperate with X-ray personnel whenever and wherever any need for help arose.

An accessory item of equipment that would have been of great value was a mop-wringer device, especially in departments in which barium enemas were given. There were apparently no words for this item in either French or Italian, and attempts to describe and obtain it were unavailing. Until the end of the war, therefore, charwomen cleaned with mops that were wrung out by hand and that were probably highly contaminated.

EVALUATION OF EQUIPMENT

The experience of the X-ray departments in the North African theater in the early phases of combat were of great value in testing equipment and determining revisions necessary in it. In the spring of 1943, within 6 months of the landings, official reports from the theater began to record data concerning the various items used and to comment on them critically. Essentially

the same comments were repeated by the hospitals that came into the theater later.

The chief difficulty with the equipment supplied all hospitals was that it was suitable only for mobile field and evacuation hospitals. The table of equipment for larger fixed hospitals was created radiologically simply by increasing the numbers of items intended for smaller hospitals. It was impossible to do the kind of work required in the larger hospitals, quite aside from its quality, without modification of the equipment provided.

The general theater opinion of this equipment is typified in the remarks of Major Lingley, Chief of Radiology, 6th General Hospital, which served in MTOUSA from 24 February 1943 to 15 June 1944. He considered the equipment generally adequate in quality and quantity, but made the following specific criticisms (*6*):

1. The X-ray field unit machine was excellent in respect to portability and durability. It produced high quality radiographs of the extremities and fairly good radiographs of the chest, but poor films of the skull, abdomen, and lower spine because of the lack of a Bucky.

2. Fluoroscopy in the horizontal position could be performed satisfactorily with the field unit, but fluoroscopy in the upright position was so difficult that it was seldom attempted. The large number of gastrointestinal and chest examinations performed in most hospitals required a good upright fluoroscope and, preferably, a tilt table. The lack of these features was a serious defect in the Army field unit.

3. The foreign body localizing apparatus included as part of the radiographic table was unnecessary. Preoperative localization of foreign bodies was best performed by careful routine fluoroscopy and appropriate films.

4. The following modifications of the field unit were recommended:

A frame tabletop should be added, with a hand crank to raise it to a vertical position.

The tube should be counterbalanced by the usual weights inside the tube column to permit free and smooth motion for upright fluoroscopy.

A light moving Bucky diaphragm should be available. Although ordinarily attached to the tabletop, it should be removable, so that it could be used for bedside examinations.

Foreign body localizing devices should be omitted.

5. Darkroom equipment was satisfactory except for inadequate space in the film drier and the short life of the cooling motor for the developing tank. A folding metal cabinet, with space for at least sixty 14- by 17-inch films would remedy the former defect. The difficulty with the motor could be obviated by the use of a metal shield to protect it from water splashing down from the tanks above.

6. At the time of this report, the 1.5-kw. field unit generator had been in use at the 6th General Hospital for only a month, but during that time 1,400 examinations had been made. The generator performed well as long as it was called upon to operate only one machine at a time and nothing else. The 30-kw. generators proved an excellent source of power. It was recommended that each X-ray department always have one for its own needs, on an independent circuit, to avoid fluctuations in voltage by overloading from other parts of the hospital. The frequency meter incorporated in later models of this generator was an improvement, since it was found that variations in frequency produced unexpectedly large variations in X-ray output.

X-ray work in the Mediterranean theater, as in other theaters, was often done under very difficult conditions, as is evident from what has just been said. Field units derived their current from low capacity sources, often from

unstable gasoline generators. Temperatures of processing solutions were seldom within the acceptable developing range. The water supply was often inadequate. Finally, the urgency with which most of the work was done was an invitation to hasty work and incomplete processing. In spite of these obstacles to proper performance, the end results were usually good and were frequently excellent.

FILMS

X-ray films were in good supply throughout the Mediterranean theater during the entire period of operation. They were all of firstline quality, and they were received in good condition, packed in waxed boxes to prevent damage from moisture. The only shortages encountered were occasional, when units were on the move.

There was also no shortage of processing chemicals. Two qualities were provided. The first grade was the variety ordinarily used in civilian radiologic practice. The second-grade chemicals provided were not always satisfactory.

The average film usage throughout the theater was 1.7 to 1.8 per case of 14-by-17 films, or the equivalent. The average for the 7 weeks represented in chart 8 (p. 242), 1.2 per case of 14-by-17 films, or the equivalent, is low and probably reflects the fact that the hospital (the 36th General) was just getting into operation. The actual film consumption for the period, during which 2,533 examinations were made (table 7), was as follows: 8-by-10 films, 1,262; 10-by-12 films, 1,162; and 14-by-17 films, 1,977.

The wastage of films in these three categories was, respectively, 28, 26, and 32 films. For the entire 8 week period shown in the chart, it was 1.7 percent, which is comparable to the usual wastage in civilian practice. Most wastage was caused by the necessity of repeating films that were unacceptable diagnostically. It varied widely, being influenced by the experience of the technicians and the circumstances of operation. In the field, with poor power and inadequate water supply, the percentage of waste was somewhat higher than in fixed installations, in which all factors were more adequately stabilized.

It might be added that the ability of Italian technicians to place numerous views of small parts on a single film was an education to U.S. technicians, who were accustomed to generous supplies of films and who used them with corresponding lavishness.

Section IV. Diagnostic Considerations

Combat-Incurred Wounds and Other Injuries

LOCALIZATION OF FOREIGN BODIES

The importance attached to the localization of foreign bodies in combat casualties was evident in the special de Lorimier device that was an integral

part of the field X-ray unit (p. 72) and the extensive training of both officers and technicians in its use. It did not prove practical. Early in U.S. participation in the war, it was used by hospitals for brief periods when they began to operate. When it was found that the required procedure was time-consuming and did not result in visualization of the multiple shell fragments present in the majority of wounds, its use was discontinued. It is unfortunate that the field unit table was designed with the major emphasis on its localizing capacities, for its mobility and its ease of operation for other diagnostic purposes were considerably restricted, as has just been pointed out.

When the use of the localizer was discontinued, localization of foreign bodies was accomplished by anteroposterior and lateral projections of the affected area, occasionally supplemented by fluoroscopic examination. During periods of excessive activity, many hospitals used only fluoroscopy.

Foreign bodies in the eyes were localized in several ways, the problem, except for its magnitude, being much the same as that encountered in civilian life. Some ophthalmologists used plastic contact lenses with inset reference points. Some used metallic reference points sutured to the globe near the site of the foreign bodies, with either stereoscopic or multiple projections. The standard Sweet technique was widely used; some hospitals, such as the 64th General Hospital, which served as an eye center, used it almost exclusively (*7*).

WOUNDS OF THE EXTREMITIES

Combat Injuries

Foreign bodies in the extremities seldom required detailed localization. Debridement was performed routinely, and most of them were removed in the course of that procedure. Instead of the anticipated problem of single foreign bodies, it was found at once that shell fragments were likely to be numerous (fig. 79). This was particularly true of injuries caused by landmines. Radiography was always preferred to fluoroscopy in wounds of the extremities. In most instances the problem was technical rather than clinical; technically good roentgenograms were essential, and, as already noted, they were often obtained under adverse conditions.

Followup studies served the usual purpose of evaluating alinement of fractures, the progress of healing, and the presence or absence of infection. The use of various orthopedic devices, such as Parham bands, Lane plates (fig. 80), Steinmann pins, and Kirschner wires required frequent radiologic checks. When roentgenograms were made after the first German POW's had been taken, it was of great interest to find that a new device, the intramedullary pin, was being employed on an experimental basis. Radiographic followup of a number of these patients established the validity of this technique for the apposition and alinement of fractures of the long bones, but it did not come into U.S. military—or general civilian—use until after the war.

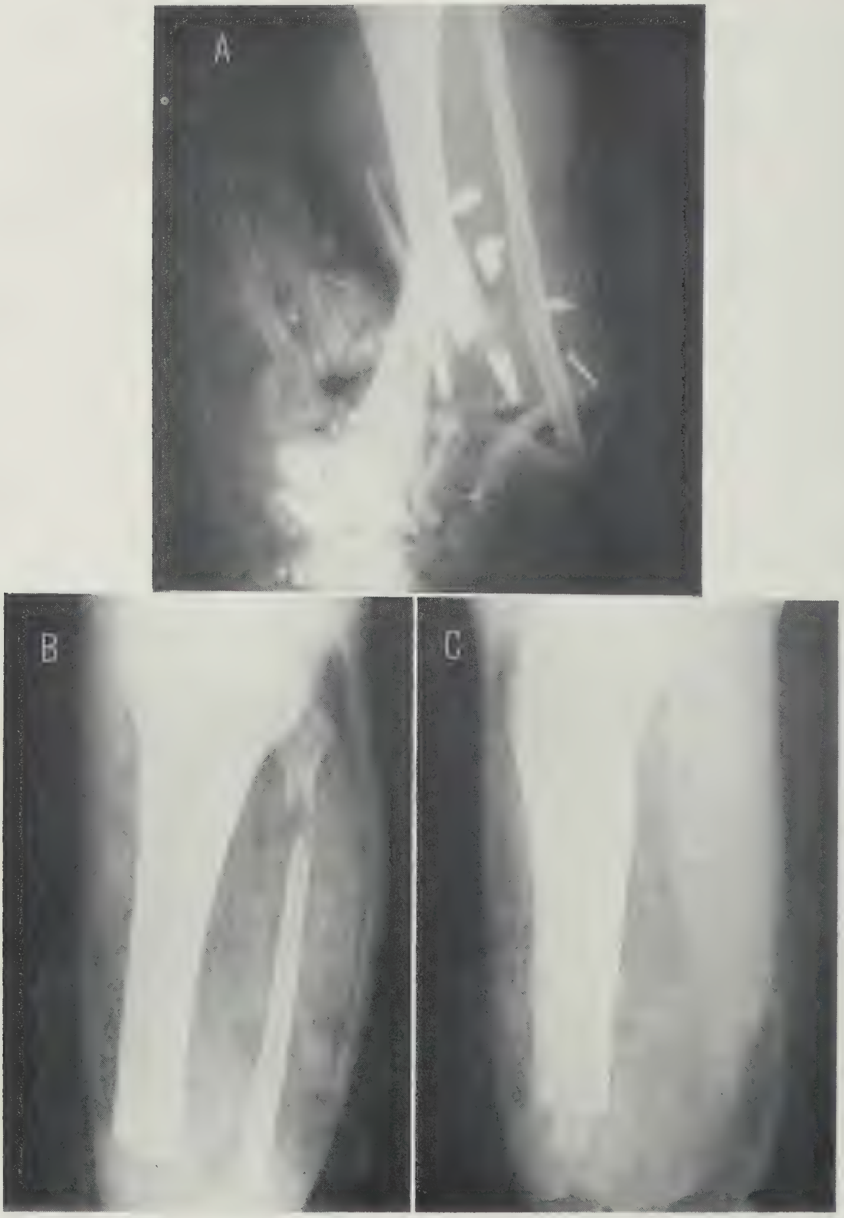


Figure 79.—Compound comminuted fracture of foot and lower leg. A. Anteroposterior projection. Note shattering of bone and numerous metallic foreign bodies from landmine. B. Postamputation stump, anteroposterior projection. Note extensive gas throughout soft tissues, following muscle bundles and fibers. C. Lateral projection.

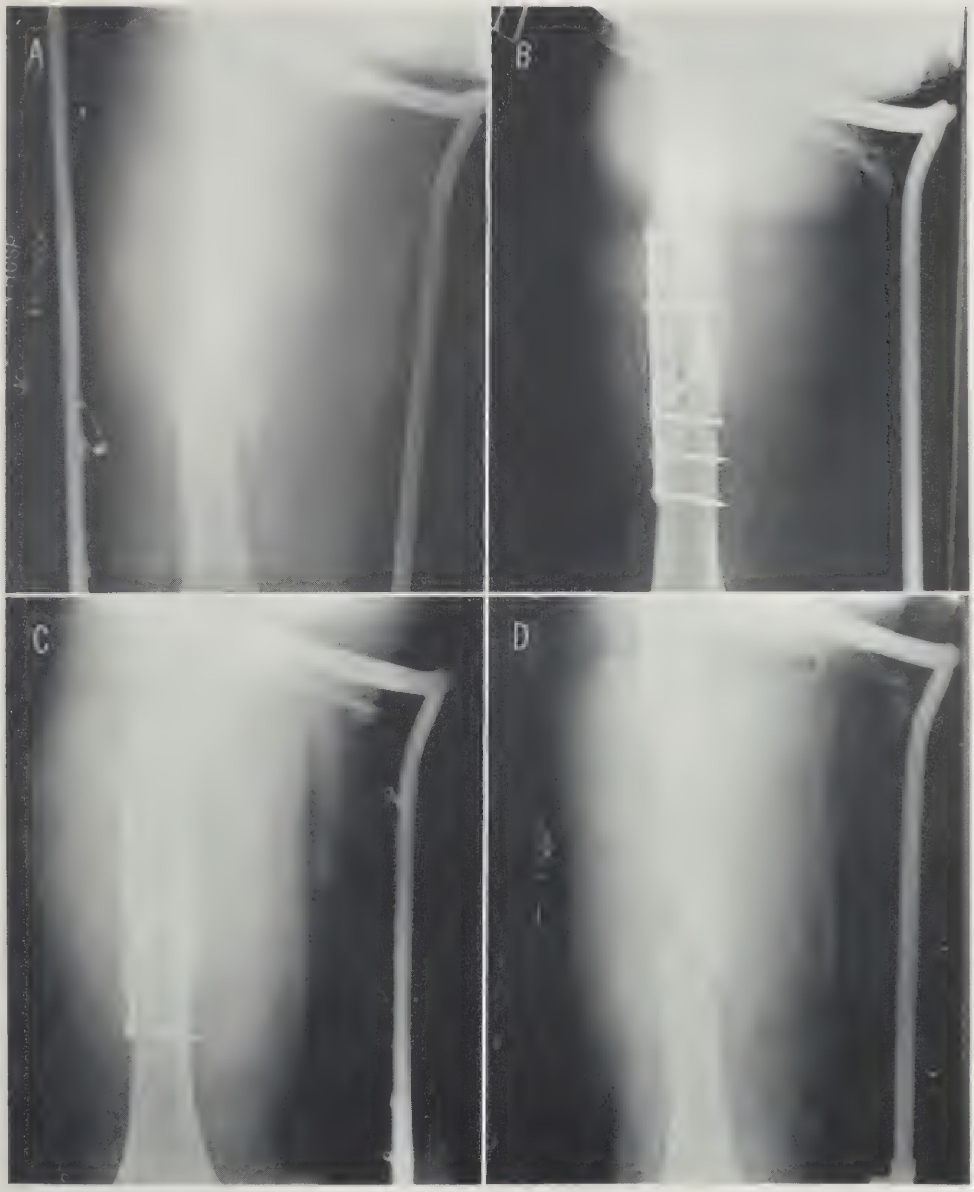


FIGURE 80.—Compound comminuted fracture of mid portion of femur. A. Anteroposterior projection. B. Anteroposterior projection 3 days later, after internal fixation with Lane plate and additional screw. C. Anteroposterior projection 6 weeks later. Note moderate callus formation, no definite evidence of osteomyelitis. D. Anteroposterior projection after removal of Lane plate because of infection and osteomyelitis. Note absence of union.

Civilian-Type Entities

Knee injuries with damage to the cartilage were frequent, and, as in the large European theater experience, one of the best techniques for evaluation of the status of the structures was pneumoarthrography. The injection of air into the joint (fig. 81) followed by radiographs taken in forced adduction and abduction became a popular and fairly accurate method.

Elective surgery for such conditions as various deformities of the feet, dislocated semilunar cartilage, and varicose veins was permitted only if the operations were likely to lead to restoration to full duty status within a relatively short time. Single X-ray examinations were therefore all that was required. Vascular competence was not evaluated by radiographic methods in World War II. It is quite likely that a higher degree of salvage of wounded extremities might be possible at this time (1963), with the judicious use of arteriography.

HEAD INJURIES

Intracranial foreign bodies required precise localization before attempts were made to remove them. Their removal was necessary, whether they were shell fragments that might have carried in with them attached hairs, lining of the helmet, or clothing, or were bone fragments, which were particularly likely to give rise to infection. These localizations were best carried out by means of film studies in multiple projections (fig. 82).

Initial radiographic screening was carried out in forward hospitals, but most detailed radiographs necessary for the management of head wounds were made in fixed hospitals in the rear. Early emergency surgery in forward hospitals, to which experienced neurosurgeons were not attached, gave unacceptable results. The practice of delayed surgery was then begun, after it was found that delays up to 72 hours in the initial surgery were a safe price to pay for the greater safety of operation in a fixed hospital, with specialized personnel and better facilities, including the assistance of experienced radiologists. Later, the establishment of special neurosurgical centers further elevated standards in the management of head injuries.

Attention has already been directed to the happy consequences of the continued association in affiliated general hospitals of neurosurgeons and radiologists who had worked together in civilian life. The work done at the 36th General Hospital is an illustration of these results. The material comprised several contributions to the periodical literature, which are described below, and two scientific exhibits, one on pneumoencephalography in penetrating cranial wounds at the Radiological Society of North America in Chicago in December 1946, and the other on penetrating cranial wounds at the meeting of the American Medical Association in Atlantic City in June 1947.[2]

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[2] Both exhibits were presented by former officers of the 36th General Hospital, Lt. Col. James E. Lofstrom, MC; Lt. Col. John E. Webster, MC; Capt. Richard C. Schneider, MC; and Capt. Donald A. Koch, MC.

FIGURE 81.—Pneumoarthrography of knee. A. Anteroposterior projection of knee, showing slight tissue swelling incidental to injury of cartilage. B. Lateral pneumogram of knee with forced adduction. Air outlines medial meniscus, which appears normal. C. Lateral pneumogram of knee with forced adduction. Note increased mobility of lateral aspect of joint and injury to attachment of meniscus.

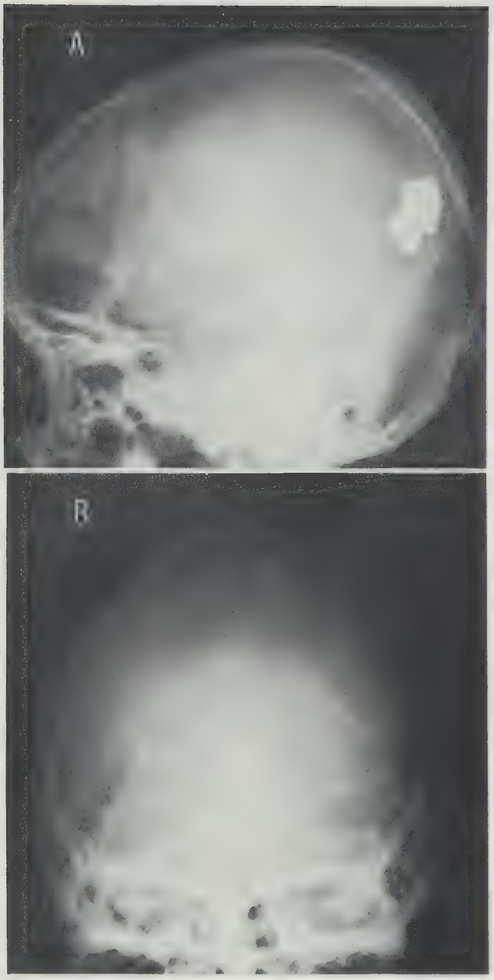

FIGURE 82.—Intracranial injury. A. Lateral projection of head, showing large craniotomy defect in frontal area at site of entrance of shell fragment and wound debridement. Note tract extending to shell fragment. B. Anteroposterior projection. Irregular margins of shell fragment carried fragments of hair, helmet liner, and cloth into the wound, providing an ideal locus for infection.

Penetrating wounds involving the cerebellum.—An analysis of 300 penetrating wounds of the head revealed only 10 (3 percent) involving the cerebellum (*8*). Five patients had been operated on at evacuation hospitals, but the cerebellar injury had been overlooked in four of the other five patients later operated on at the 36th General Hospital. The diagnostic error was serious, for wounds of the cerebellum, with their possibilities of rapid and serious complications, were usually considered priority cases for forward surgery. In three of the four cases in which the diagnosis was missed, the injuries were overlooked because the wounds of entrance were in the neck. It was concluded that even apparently minor wounds of the posterior neck might be associated with intracranial injury and should be investigated, radiologically and otherwise, from that standpoint. With adequate preoperative

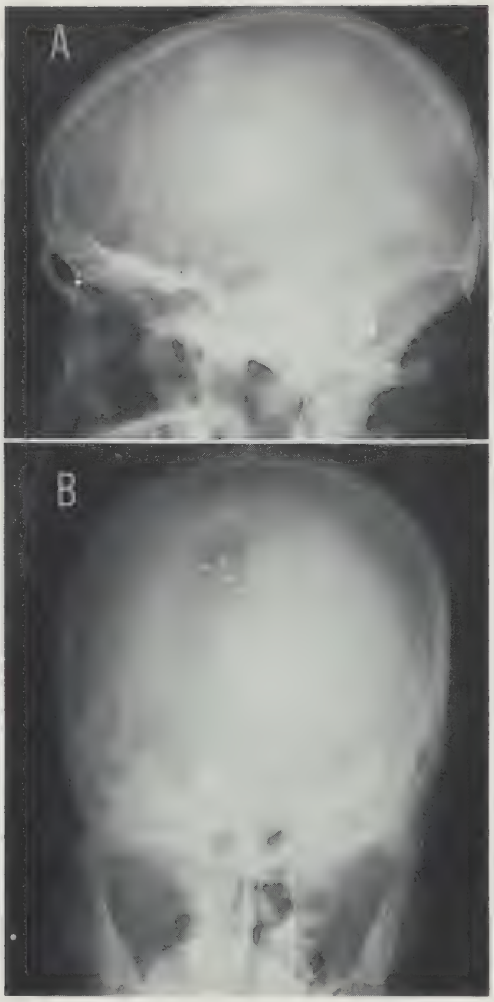

FIGURE 83.—Shell fragment residual in cerebellum after operation at evacuation hospital. A. Lateral roentgenogram. B. Towne projection showing extensive craniotomy defect with residual shell fragment.

X-ray studies showing the location of the foreign bodies (fig. 83) and the degree of injury, most complications could be avoided.

Orbitocranial wounds.—In the same 300 cases of penetrating wounds of the head observed at the 36th General Hospital were 40 in which the fronto-orbital area of the skull was involved and both orbit and brain were damaged (*9*). These wounds presented particularly difficult technical problems to the roentgenologist. At the time of the initial examination, the condition of the patient often prevented the usual type of positioning for the frontal, axial, or Waters' projections. In such instances, the head was turned into the horizontal plane and the beam was projected at the usual angle. Detail could be enhanced by the use of a wafer-type grid. If the patient's condition permitted, studies were made in the upright position, utilizing the vertical

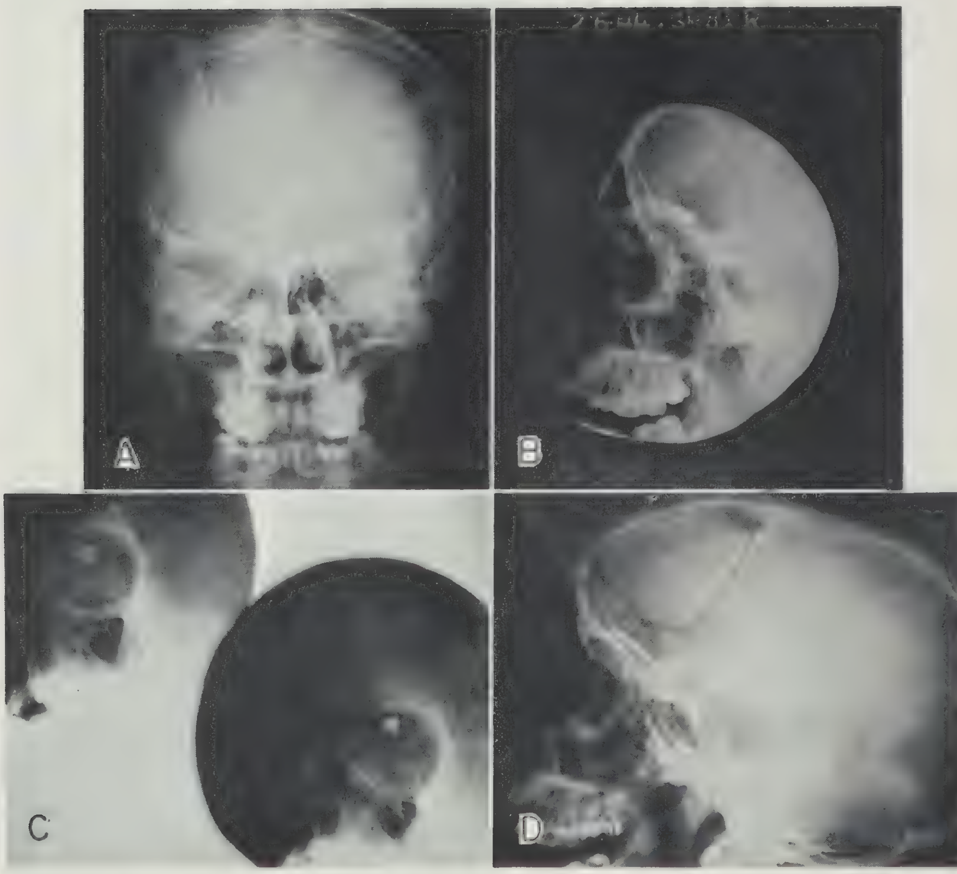

Figure 84.—Localization of shell fragment of frontal fossa with orbital penetration. A. Posteroanterior roentgenogram. B. Lateral roentgenogram for more precise localization. C. Orbital (optic foramina) projections, showing site of penetration of fragment through orbit into frontal fossa. D. Lateral roentgenogram after removal of foreign body and closure of dura. Note frontal flap.

Bucky-Potter diaphragm. Whenever possible, bulky dressings were removed to minimize distortion.

Routine examination included, as a minimum, right and left lateral projections and occipital, frontal, and Waters' axial or verticomental projections. Detailed orbital films were also made, to visualize the optic foramina (fig. 84). If the patient's condition permitted and the necessary equipment was available, stereoscopic films were also made. The smallest possible cone was used.

A study of these roentgenograms usually indicated the extent of the frac-

ture lines in the fronto-orbital area and visualized the pathway of a penetrating metal fragment. Extension of the fracture lines into the frontal, ethmoidal, and sphenoidal sinuses or the optic foramina, and visualization of depressed or indriven bone fragments, constituted useful preoperative information for the neurosurgeon.

The experience with these 40 orbitocranial wounds indicated that surgical treatment could safely be carried out in a general hospital, where experienced neurosurgeons could care for them and the radiologic diagnostic refinements just described were available.

Brain abscess complicating penetrating wounds of the cranium.—Brain abscesses developed after operation in 33 of 206 penetrating wounds of the brain cared for at the 36th General Hospital (*10*). Ten of these occurred in German POW's, eight of whom had been treated at a POW hospital under difficult conditions. Primary debridement had been performed at U.S. evacuation hospitals on all but 2 of the 33 patients.

There were two important considerations in the diagnosis of a complicating brain abscess, (1) the presence of an infected wound and (2) the presence of retained bone fragments in the cerebrum after primary debridement (fig. 85). Only 3 of the 33 patients had healed wounds. Retained bone fragments were demonstrated in 19 instances and metallic foreign bodies in 12. The role of roentgenology in the identification of these foreign bodies is obvious. Roentgenograms were made in various projections in all cases, and in several, in which the diagnosis was in doubt, encephalograms were also secured. The size of the metallic fragment was significant in terms of the track of damage produced, and its irregularity (fig. 82) was also of importance in relation to its ability to carry contaminating material. The metal fragments shown on roentgenograms to have ragged outlines were invariably found loaded with organic material. In only 1 of the 19 cases in which bone fragments were present were they found to be sterile.

Pneumoencephalography.—The combined neurosurgical and radiologic staffs of the 36th General Hospital made pneumoencephalographic studies in 23 of 256 patients with penetrating wounds of the brain, in 206 of which dural penetration had occurred (*11*). The majority underwent initial wound surgery in evacuation hospitals.

These patients were divided into two groups, according to the phase of operations in Italy and southern France during which they were treated.

1. In the first group, which consisted of 146 patients, 119 of whom had sustained dural penetration, routine roentgenograms revealed the presence of retained bone fragments within the brain after primary debridement in 16 cases (11 percent) and retained metallic fragments in 39 cases (27 percent).

2. The second group consisted of 110 patients, 87 of whom had sustained dural penetration without retained fragments.

The time at which the pneumoencephalograms were made varied from 14 to 90 days after the original injury, which was the time at which primary debridement was performed.

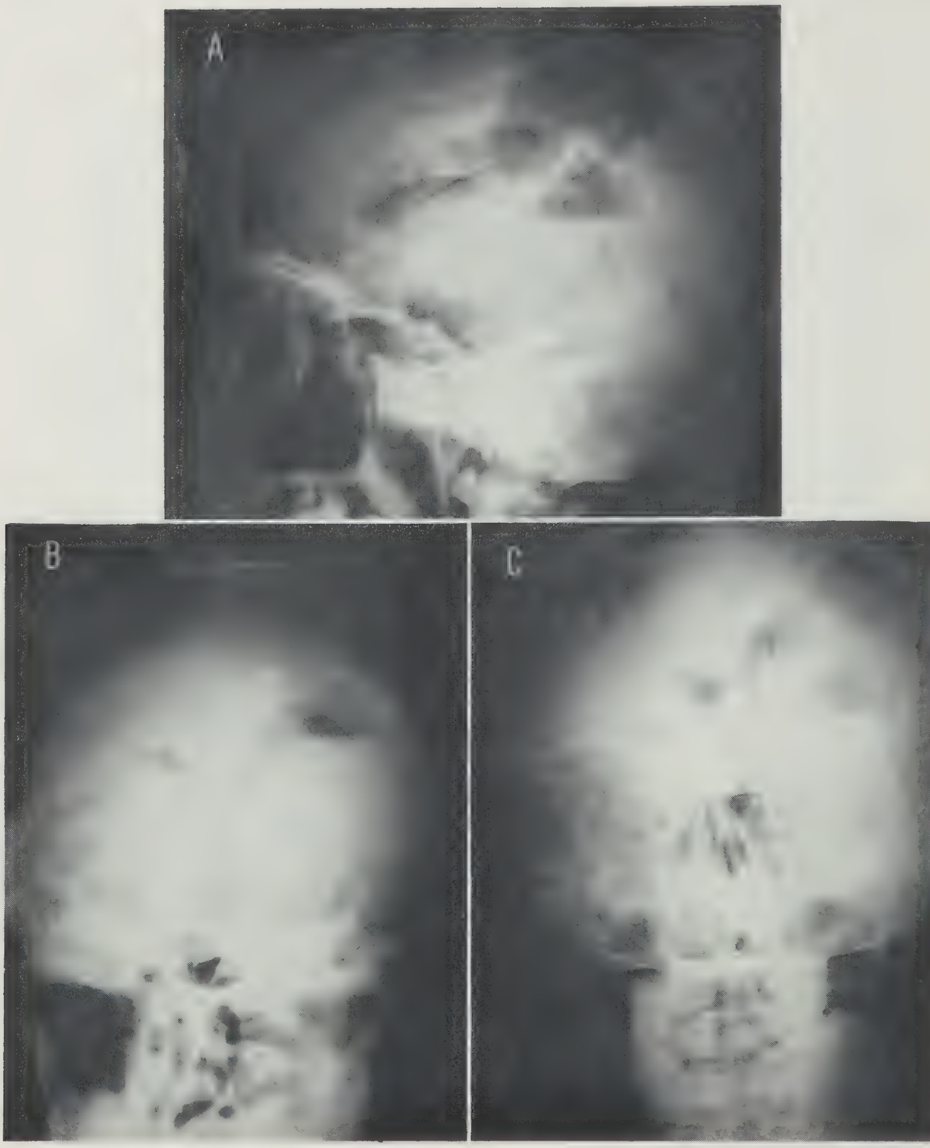

FIGURE 85.—Residual intracranial bone fragment with abscess formation. A. Lateral roentgenogram of skull showing dense linear shadow of residual bone fragment after primary debridement. Note craniotomy defect. Note also fluid level in abscess cavity posteriorly just below bone fragment. Ventricles are outlined anteriorly. B. Posteroanterior roentgenogram showing bone fragment and abscess cavity. Lateral ventricle is elongated and displaced by mass of abscess. C. Anteroposterior roentgenogram showing relation of abscess cavity to distorted lateral ventricle. There is no subarachnoid space residual on infected side but good space contralateral.

In the entire group of 23 cases, only three roentgenograms showed a normal subarachnoid air pattern. The remainder demonstrated either localized or generalized obliteration of air shadows. Ipsilateral ventricular enlargement seemed the usual pattern after debridement of a wound of the brain. As the degree of tissue loss increased, the ventricular enlargement became more diffuse, in one case reaching 200 percent of normal. In another case, however, the ventricular system was normal in spite of a significant loss of tissue; the bony defect in this case was 4 cm. in diameter. A severe loss of cerebral substance usually resulted in dilatation of the contralateral, as well as the ipsilateral, ventricle, and a shifting of the entire system to the affected side (figs. 86, 87, and 88).

At this early period after wounding, the ventricular distortions observed appeared to be related to the loss of brain tissue rather than to the size of the bony defect produced by craniectomy. They were usually proportional to the amount of the tissue loss. Closure of the dura at operation did not seem significant; marked ventricular distortions occurred with small bony defects and in the presence of a tightly closed dura or dural graft.

The pronounced degree of dilatation that was observed in several patients in this group soon after debridement left little doubt that the change was on the basis of hydrodynamic compensation: A definite volume of brain tissue had been removed, and the space was filled first by fluid or by swollen brain substance and later by dilatation of the ventricles, which was the result of the positive pressure of the cerebrospinal fluid. The ipsilateral shift of the system was evidence of further compensation. Contralateral shift, which was demonstrated in four cases, was suggestive evidence of a mass lesion complicating the original trauma.

Arachnoiditis was a common finding, and, whether it was localized or generalized, it was assumed to indicate a significant disruption of the normal mechanism of cerebrospinal fluid elimination. Although a number of the wounds of the brain communicated with the ventricle, persistent loculation of cerebrospinal fluid in the cavity created at operation did not develop.

In spite of the clearly demonstrated hydrodynamic changes on the pneumoencephalograms, headache was uncommon in uncomplicated wounds and convulsions were relatively infrequent in the period these patients were under observation. The progressive ventricular dilatation observed in two cases suggested that in other cases the future course would be in the direction of continuing dilatation.

Pneumoencephalography was considered a useful method for determining possible complications, such as brain abscess or subdural hematoma, when clinical studies alone were inconclusive.

MAXILLOFACIAL INJURIES

A survey in MTOUSA, completed in October 1943 and covering 12 hospitals, yielded 243 cases of maxillofacial injury, 42 percent of which were

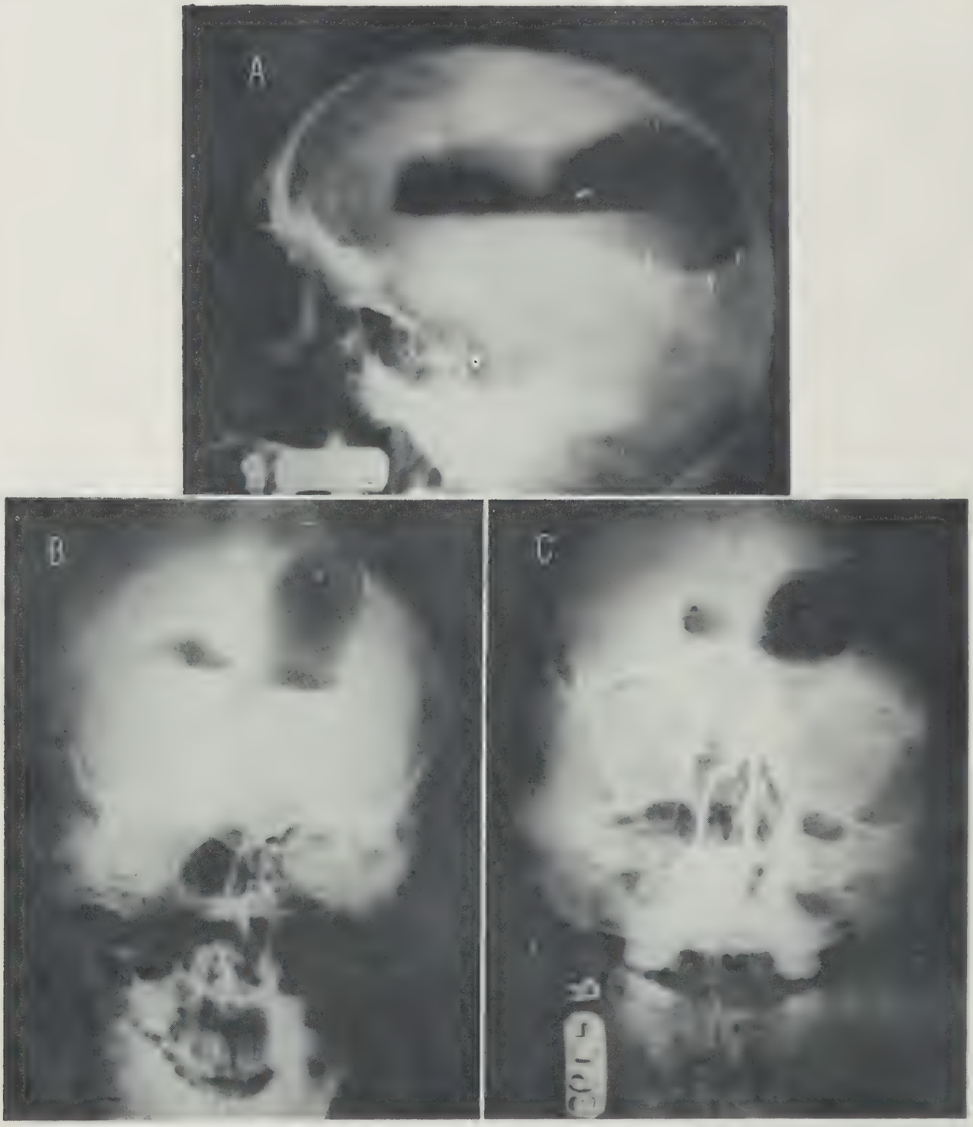

FIGURE 86.—Pneumoencephalography in abscess formation. A. Pneumoencephalogram of patient shown in figure 85 after drainage of abscess in lateral hemisphere. After operation there was immediate marked dilatation of ipsilateral ventricle with slight shift to this side. B. Posteroanterior roentgenogram. C. Anteroposterior roentgenogram.

combat-incurred (*2*). Lack of precise definition of diagnosis and cause in hospital reports made the exact incidence in battle casualties uncertain. It was estimated, however, that about 30 percent of the battle casualties and about 70 percent of the patients with accidentally-incurred injuries were returned to duty because their injuries were not severe or mutilating. The sur-

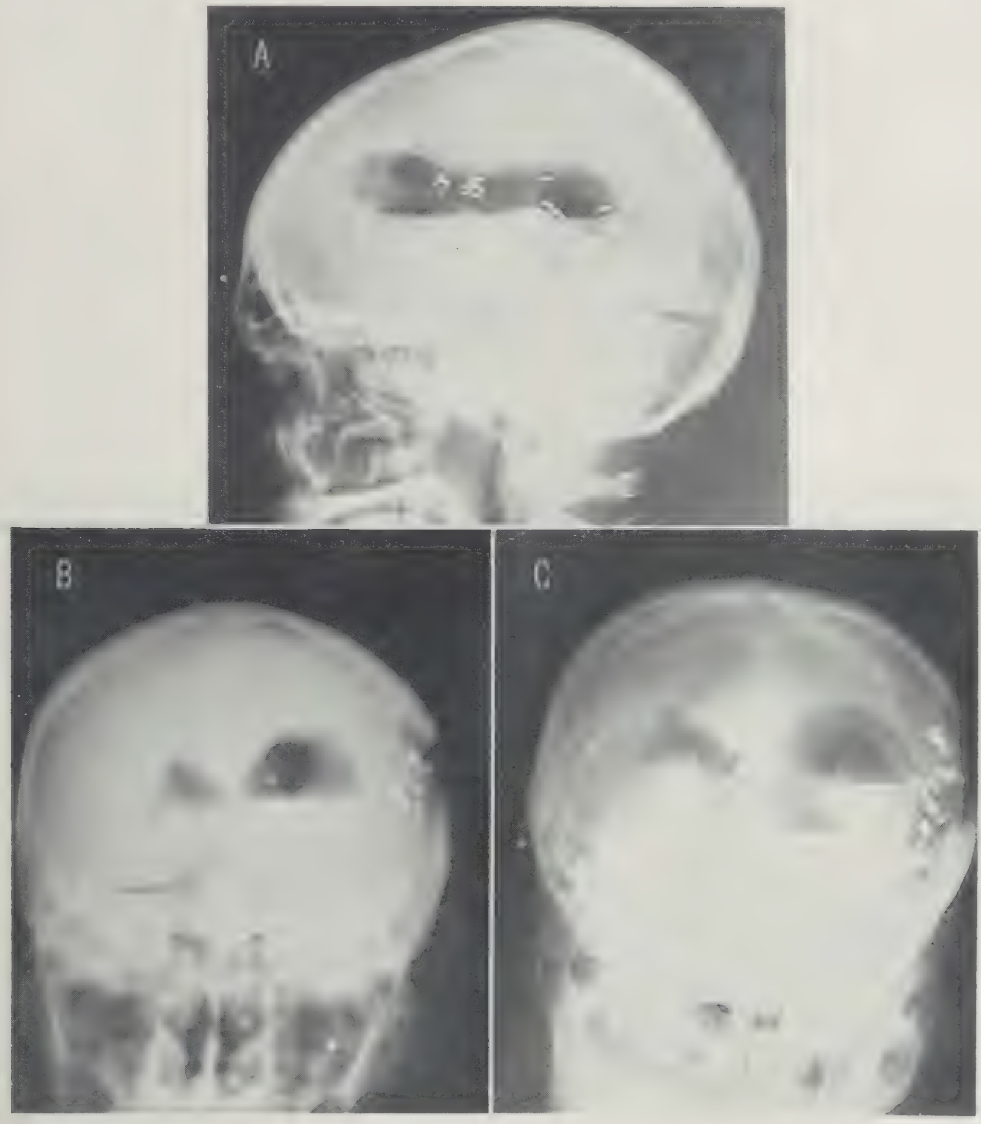

FIGURE 87.—Penetrating wound of skull with extensive frontoparietal fracture. A. Lateral roentgenogram 3 weeks after operation. Note generalized enlargement of ipsilateral ventricle. B. Posteroanterior roentgenogram. C. Anteroposterior roentgenogram.

vey indicated that a lack of experienced surgical personnel, plus the wide dispersion and small number of such injuries, made professional coverage of the forward areas by experienced personnel in the field of maxillofacial surgery difficult to accomplish. The establishment of special maxillofacial centers in base sections was therefore a wise solution of the problem. In these centers,

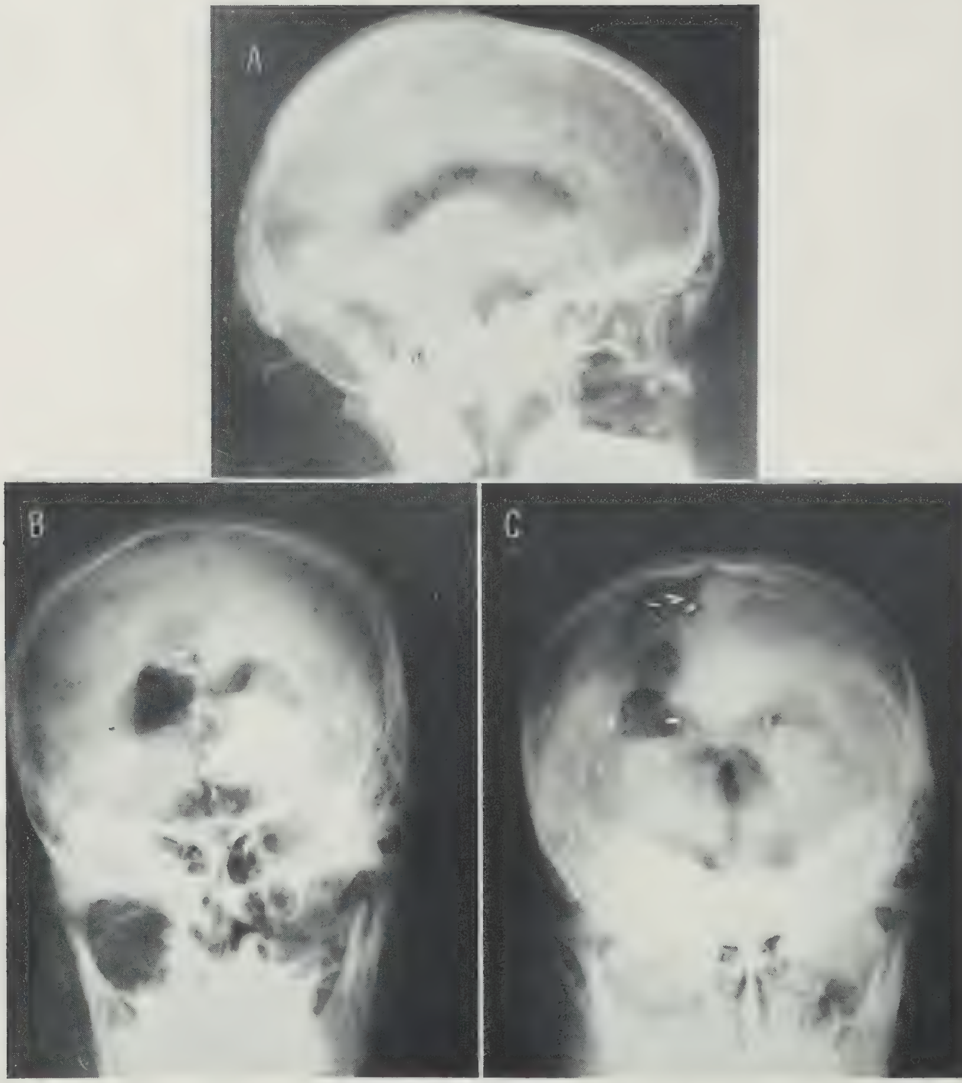

FIGURE 88.—Pneumoencephalography in wound of posterior fossa. A. Anteroposterior pneumoencephalograph, after operation, showing fairly large occipital craniotomy defect. B. Posteroanterior projection showing enlargement of occipital horn of lateral ventricle, with slight generalized ventricular dilatation. C. Posteroanterior view.

the combined efforts of oral, maxillofacial, otolaryngologic and ophthalmic surgeons and neurosurgeons were brought to bear on the problem, in which radiologists also played a major role.

In civilian practice, there is probably no region in the body in which exact diagnosis by radiologic methods is more challenging than in the maxillofacial area. The challenge was greater in combat-incurred injuries when the diag-

nosis had to be made with limited equipment and accessories. Refined techniques were necessary, and it was the common experience that the more involved and complicated positioning techniques could be accomplished only by experienced technicians.

WOUNDS OF THE SPINE

The radiologic evaluation of problems referable to the spine and spinal cord was essentially the same as for those encountered in civilian practice. The chief diagnostic difficulty was the lack of radiographic equipment of sufficient capacity for detailed film studies, compounded by the frequent lack of a Bucky diaphragm. Fractures of various areas were not uncommon as the result of accidental injuries, but they presented no unusual complicating features (*12*).

The management of penetrating wounds of the spine was determined in large measure by the roentgenologic findings. A study of 94 patients with such wounds observed at the 36th General Hospital is typical of these wounds and their management but atypical in that the Medical Corps officers who had treated them overseas were able to follow up, and report on, 56 of the 69 from 2 to 3 years after the war (*13*). Since no attempt was made to investigate the 25 casualties in the group who were not in the U.S. Army (they were chiefly German POW's), the followup may be considered remarkably successful.

When these patients were received at the 36th General Hospital, laminectomy was performed on 38 for two reasons, that they had had no primary debridement in forward hospitals or that the debridement performed had been only superficial.

All patients with spinal injuries received in the hospital were managed by the same plan, which included lumbar puncture, Queckenstedt's test, a complete neurologic survey, and radiologic examination. Laminectomy was performed when the roentgenograms showed the presence of bone or metallic fragments within the spinal canal (figs. 89 and 90), when a spinal fluid block was demonstrable, or when the so-called dynamic syndrome developed, with progressive disability. It was the usual experience to find at operation that the comminution of bone in and about the spinal canal was of greater degree than the preoperative roentgenograms had suggested. This finding further emphasized the importance of good detail in radiographs of the spinal area.

It was also observed that the spinal wound was sometimes overlooked in forward areas, not because of failure to make roentgenograms of the affected area but because of distortion of the roentgenograms, some of which failed to show even large metallic fragments in and about the canal (fig. 91). The explanation of this observation, like the observation made just above, was inadequacy of the equipment available and the inexperience of the X-ray technicians.

While the followup of these 55 patients (1 was found to have died after return to the Zone of Interior) was clinical (chiefly neurologic) and occupa-

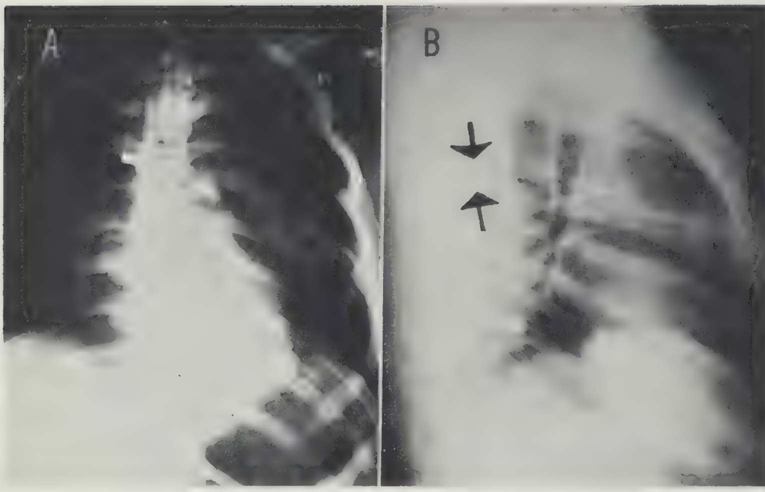

FIGURE 89.—Shell fragment wound of thoracic spine. A. Anteroposterior roentgenogram showing shell fragment embedded in right lateral aspect of fifth thoracic vertebra, after coursing over from left side and fracturing sixth costovertebral juncture. B. Lateral roentgenogram showing fragment embedded at level of fifth thoracic vertebra.

tional, the brilliant results achieved by the Army paraplegic program should be mentioned. It is described in detail in the second neurosurgical volume of this historical series (*12*). Of the 55 patients, 16 had no neurologic disability. Of 19 who were originally completely paraplegic, 4 had partially recovered and 5 others had been rehabilitated to the point of ambulation with braces. In the whole group, 23 were engaged in earning all or part of their support or were continuing their education; of the 15 complete paraplegics, only 8 were completely dependent.

WOUNDS OF THE CHEST

The localization of intrathoracic foreign bodies was often of great importance, especially when the fragments came to rest in the proximity of vital structures in the mediastinum (fig. 92). Their location was also important when the integrity of the diaphragm was in question (p. 305).

Multiple radiographic projections, combined with fluoroscopic observation, usually provided the essential information the surgeon needed and occasionally provided the fluoroscopist with the dramatic sight of a shell fragment bouncing vigorously within one of the cardiac chambers. Serial observations were also sometimes necessary to determine the movement of foreign bodies. In one such case (fig. 93), the first examination, in a forward hospital, showed that a bullet that had entered through a wound of the neck was then in the hypopharyngeal area. A second examination, at the 36th General Hospital,

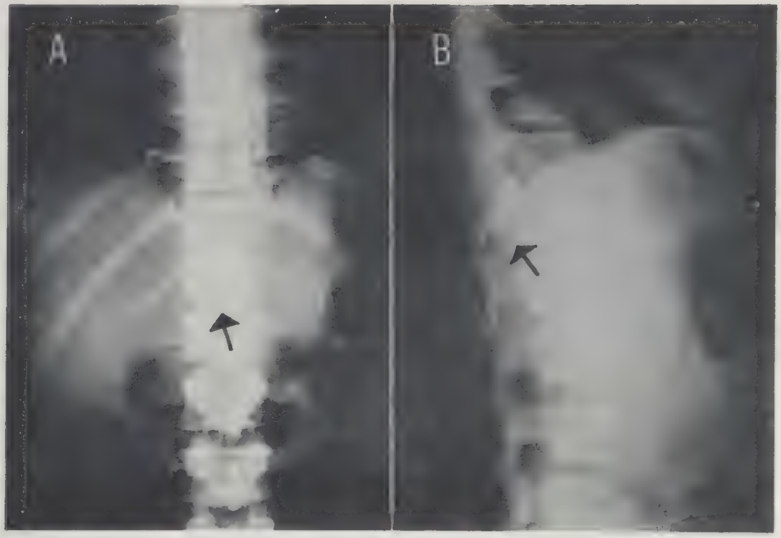

FIGURE 90.—Shell fragment wound of thoracolumbar spine. A. Anteroposterior projection showing large metallic fragment in midline opposite T_{12}. B. Lateral projection, localizing large, irregular foreign body directly in spinal canal.

showed it in the area of one of the major bronchi. Before bronchoscopy could be carried out, the patient had a severe coughing spell and expelled the bullet himself.

Even a partial list of publications from hospitals in the Mediterranean theater is indicative of the enormous interest of surgeons and radiologists in wounds of the chest. Three scientific exhibits were also presented after the war.[3] Two, entitled "The Captive Lung," were presented, respectively, at the annual meeting of the American Roentgen Ray Society in October 1949 and at the meeting of the Trudeau Society in January 1949. The third exhibit, presented in May 1949, at the meeting of the National Tuberculosis Association, was entitled "Decortication of the Lung."

The most comprehensive study of roentgenologic aspects of battle wounds of the chest was published by Maj. Max Rakofsky, MC, and Capt. (later Maj.) Victor P. Satinsky, MC, 300th General Hospital (*14*). If this report is read in conjunction with an earlier analysis of 320 penetrating wounds of the chest by Maj. (later Lt. Col.) William M. Tuttle, MC, and his associates at the 36th General Hospital (*15*), the reader will emerge with a truly comprehensive appreciation of the important aspects of radiology in these injuries. Both studies are of particular interest in that they cover the two periods of

[3] All three exhibits were presented by former officers of the 36th General Hospital, Colonel Lofstrom, Captain Koch, and Lt. Col. William M. Tuttle, MC. Drs. Paul V. O'Rourke and Edward J. O'Brien, associates of Dr. Tuttle in his civilian practice, also participated in the exhibit on decortication of the lung.

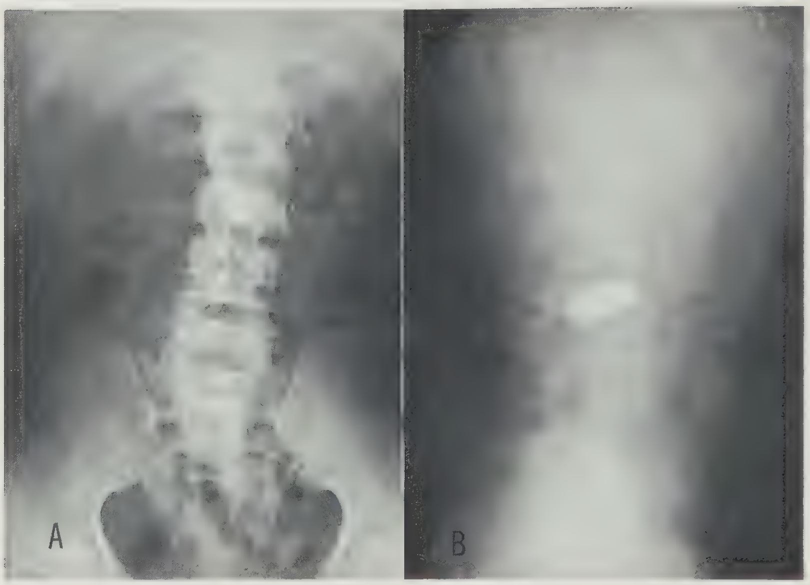

FIGURE 91.—Shell fragment wound of lumbar spine. A. Anteroposterior projection showing large metallic fragment, which had not been detected in field hospital, embedded in body of L_3. B. Lateral projection, which further localizes position of fragment within vertebral body and adjacent to spinal canal. This patient later developed osteomyelitis of the vertebral body.

the management of these wounds, the first, ending in May 1944, when it was the general practice to perform thoracotomy in forward hospitals, and the second, extending to the end of the war, when it became the practice, with corresponding improvement in results, to defer such surgery until the patient reached a fixed hospital (*16*).

Major Rakofsky and Captain Satinsky carefully pointed out the different roles of radiology in forward and in base hospitals, correlating them with the surgical mission in these hospitals:

1. The treatment of thoracic wounds in the field is primarily devoted to lifesaving measures, such as the control of shock and hemostasis, and, of equal importance, the correction of cardiorespiratory imbalance caused by open and tension pneumothorax, cardiac tamponade, stove-in chest, massive hemothorax, and massive atelectasis. For the accurate diagnosis and proper treatment of these conditions, and for the demonstration of foreign bodies and thoracoabdominal wounds, the surgeon depends a great deal on roentgen findings.

2. At the base hospital, where definitive treatment is carried out, roentgenography assumes "a wider, if less dramatic, scope in the management of thoracic injuries." At this echelon of medical care retained foreign bodies are localized; fractures of the thorax are described; and such complications as

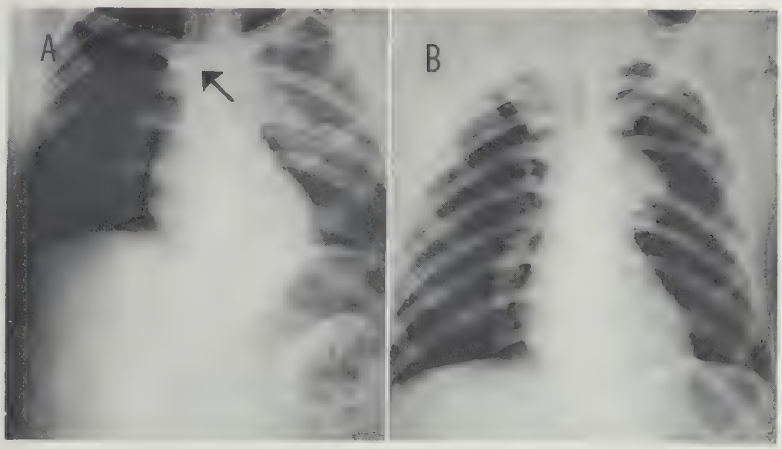

FIGURE 92.—Shell fragment wound of chest and spine. A. Anteroposterior projection, showing fragment on right, after penetrating left pleura, lung, and mediastinum and going on to vertebra. B. Anteroposterior projection after operation and removal of fragment. Note residual localized paravertebral-paramediastinal hematoma.

pneumothorax, hemothorax, pulmonary contusion, and empyema are carefully evaluated.

Major Rakofsky and Captain Satinsky included in their excellent report the radiographic techniques available for the study of intrathoracic wounds and other conditions, including:

1. Routine upright posteroanterior and lateral depictions.
2. Overpenetrated films.
3. Anteroposterior depictions in the lateral recumbent position.
4. Right and left oblique depictions.
5. Stereoscopy.
6. Roentgenoscopy.

They also described the technical factors utilized for each of these positions (table 9). They did not mention kymography, which was employed, with improvised equipment, in at least two general hospitals in the theater.

Finally, these observers reviewed comprehensively the various aspects of both open and closed injuries of the chest, with the specific X-ray findings in such conditions as injuries of the bony thorax, pulmonary concussion (parenchymal hematoma), subcutaneous emphysema, pneumothorax, loculated or encapsulated hemothorax, clotted pneumothorax, empyema, atelectasis, blast injuries, transdiaphragmatic injuries, and missile tracks. It was of adjunct value in the diagnosis and evaluation of pericardial hematoma with cardiac tamponade.

Special Conditions and Complications

Blast injuries.—Concussive injuries of the lungs were seen in patients subjected to explosions in which compressed air acted upon the thorax and

FIGURE 93.—Bullet wound of hypopharyngeal area. A. Lateral projection showing bullet at original examination in forward hospital. B. Lateral projection at general hospital, showing absence of bullet from original position in hypopharyngeal area. C. Posteroanterior projection showing bullet now in right lower lobe bronchus. D. Posteroanterior projection showing absence of bullet, which was coughed up before planned bronchoscopic removal.

altered the intrabronchial pressure. The usual roentgenologic manifestations were areas of parenchymal density indicative of hemorrhage within the lower lobes and diffuse areas of parenchymal haziness associated with edema (fig. 94).

TABLE 9.—*Factors utilized in study of thoracic injuries in battle casualties*

Technical factors	Postero-anterior chest erect routine technique	Lateral chest erect routine technique	Oblique views erect	Recumbent lateral antero-posterior projection	Recumbent antero-posterior	Recumbent lateral chest	Overpenetrated films			
							Postero-anterior erect	Lateral erect wafer grid	Bucky-Potter grid	
									Antero-posterior recumbent	Lateral recumbent
Anode-screen distance	72"	72"	72"	36"	36"	36"	72"	72"	36"	36"
Milliamperes	150 (large focus)	150	150	150	150	150	150	150	30 (small focus)	30 (small focus)
Milliampere-seconds	15	15	15	15	10	15	15	50	120	90
Time	1/10 sec.	1/10 sec.	1/10 sec.	1/10 sec.	1/20 sec.	1/10 sec.	1/10 sec.	1/3 sec.	4	3
Average kilovolts (peak) (depending on width of part)	68	85	78	62	64	70	78	85	66	80

Source: Rakofsky, M., and Satinsky, V. P.: Roentgenological Aspects of Battle Injuries of the Chest. Am. J. Roentgenol. 57: 583–600, May 1947.

FIGURE 94.—Anteroposterior roentgenogram of chest, showing extreme pulmonary edema and hemorrhage 24 hours after blast injury.

Mediastinal hematoma.—Mediastinal hematoma with subsequent mediastinitis occurred as a result of both closed and open injuries of the chest, more particularly open injuries. A widening of the mediastinal shadow was usually the first radiologic evidence of abnormality (fig. 95), associated with emphysema confined to the mediastinum or extending from the mediastinum into the cervical area. The integrity of the esophagus had to be conclusively demonstrated in such cases, for surgery was indicated if a perforation were present. Serial roentgenologic studies were of great importance in all mediastinal involvement.

Cardiac injuries.—In most instances of cardiac perforation, death occurred promptly and no radiologic studies were made. If, however, the injury was sustained near a hospital, the casualty occasionally survived to undergo surgery, with postoperative survival in some instances.

Numerous instances of hemopericardium were demonstrated by roentgenograms after penetrating wounds (fig. 96). Cardiac tamponade was usually diagnosed by fluoroscopy, coupled with clinical evidence of cardiac

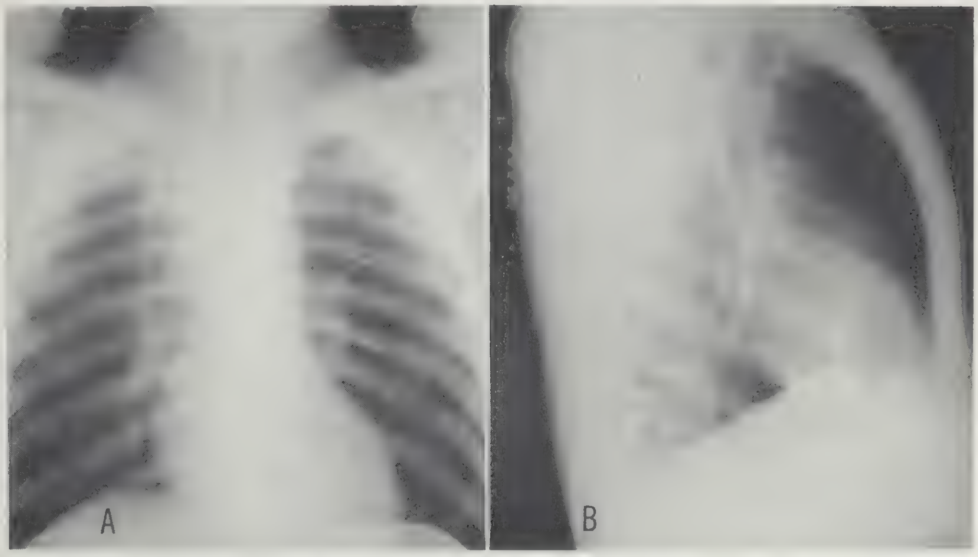

FIGURE 95.—Perforating anterior wound of chest. A. Posteroanterior view of chest, showing widening of upper mediastinum, with lack of distinction on right. Note evidence of slight local emphysema. B. Lateral view, showing intact esophagus and trachea.

embarrassment. The presence of a foreign body in the cardiac area (fig. 97), together with a total absence of pericardial pulsations, was conclusive. The diagnosis was made by kymography in a few instances (p. 293).

Pneumothorax.—Pneumothorax was of such frequent occurrence in penetrating wounds of the chest that it was regarded as a part of the initial pathologic process rather than as a complication. Serial roentgenograms were of great importance after primary debridement and closure of sucking wounds (fig. 98). Closure of the wound, however essential, was sometimes followed by tension pneumothorax, in which the continuing buildup of intrathoracic pressure could produce embarrassment of the pulmonary vascular flow and severe pulmonary dysfunction. Roentgenographic studies demonstrated the increasing size of the pneumothorax and the gradual shift of the mediastinal structures to the intact side. The efficacy of treatment, either by simple aspiration or closed suction, was also demonstrated by serial roentgenography, as was the development or lack of development of complications.

Hemothorax.—Studies on hemothorax and the development of an effective treatment for it, which are described in detail in the second volume on thoracic surgery in this historical series (*17*), represent one of the major contributions of the Mediterranean theater.

Bleeding into the thoracic cavity was, like pneumothorax, a part of the original pathologic process in chest wounds. After only a short time, simple aspiration became the routine method of treatment. Roentgenologic studies were necessary immediately after wounding and were repeated serially in

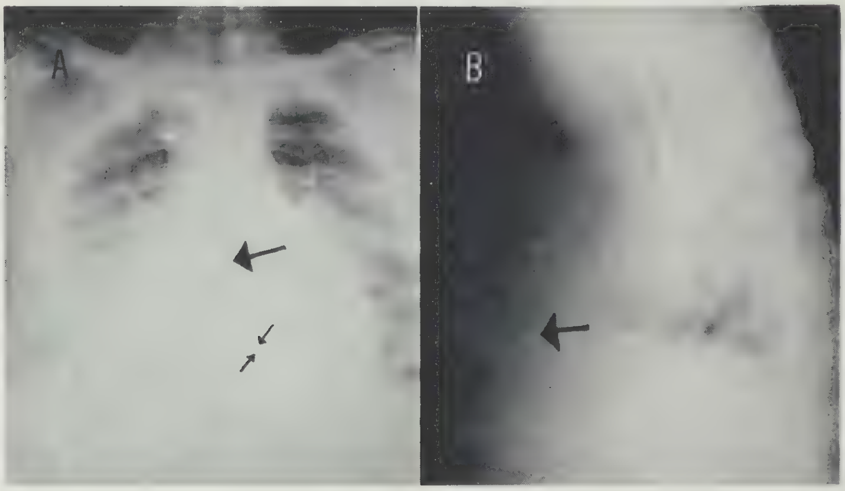

FIGURE 96.—Wound of right ventricle. A. Posteroanterior roentgenogram showing foreign body in right ventricular wall after penetrating right lateral chest wall. Note large hemopericardium. B. Lateral projection showing massive cardiac enlargement and hematoma of right lower lobe. Fluoroscopically, though pulsations were absent over the margins of the heart, the bullet could be seen moving with right ventricular contractions.

cases in which continued bleeding was recognized or suspected, so that surgical intervention could be carried out if repeated aspirations did not empty the chest.

In cases in which clotting of the contained blood occurred (fig. 99), either in spite of or in the absence of effective aspiration, the development was recognized by roentgenograms which showed opacification of the pleural space and the underlying lung. If the pathologic process went on to fibrosis, serial roentgenograms showed a progressive decrease in the overall volume of pleural density and an associated decrease in the volume of the underlying lung. It came to be realized that these findings were the result not only of simple atelectasis following compression of the affected lung but also of infolding of portions of the lower lobes with either the middle lobe or the lingula of the left upper lobe. The functional capacity of the lung was seriously impaired, and the picture was often further complicated by infection.

The roentgenologic findings in organizing hemothorax, as pointed out by Colonel Lofstrom, Capt. Donald A. Koch, MC, and others, were characteristic. One specific finding was the triangular density situated posteriorly and seen in lateral projections (figs. 100 and 101), in contrast to the generalized obscuration of the pleural space seen in the posteroanterior projection. Many surgeons came to believe that a diagnosis of organizing hemothorax was not justified if the lateral film did not reveal this typical finding.

Differentiation between a simple infolded lung and an organizing hemothorax was made by the early predominance of pneumothorax or the presence

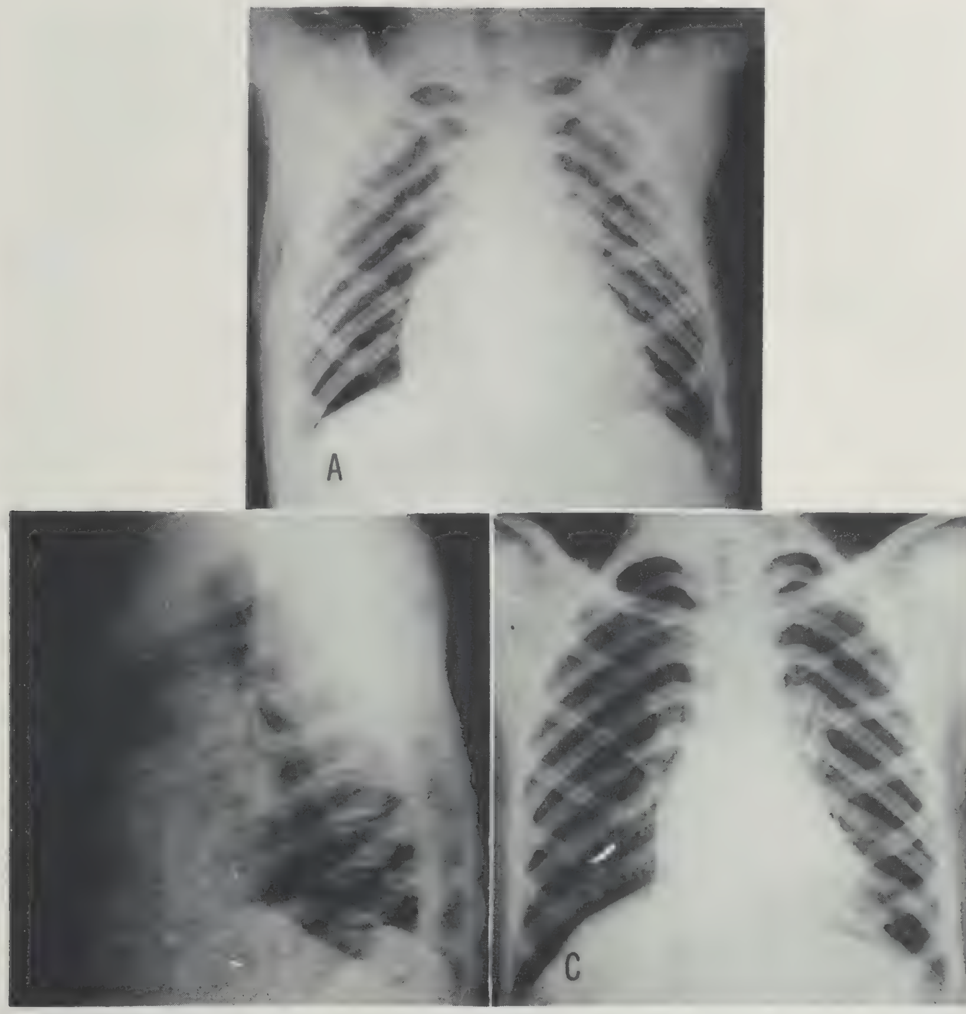

FIGURE 97.—Wound of pericardium. A. Anteroposterior projection of chest showing moderate cardiac enlargements, loss of cardiophrenic angles, and slight widening of cardiac base. Fluoroscopically no pulsations were visible. B. Lateral projection, showing good angle maintained posteriorly and partial obliteration of anterior window. C. Posteroanterior projection 2 months later, after closure of pericardial wound and evacuation of pericardial hematoma.

of recurring small amounts of serous fluid, and, particularly, by the findings on the lateral X-ray. In organizing hemothorax, the opacity was posterior and basal, whereas in infolded lung, the obscuration was patchy, diffuse, and without localization.

The management of the so-called captive lung in the Mediterranean theater, where its important implications were first comprehended, was the revival of the operation of decortication, first used by Fowler in 1893, for

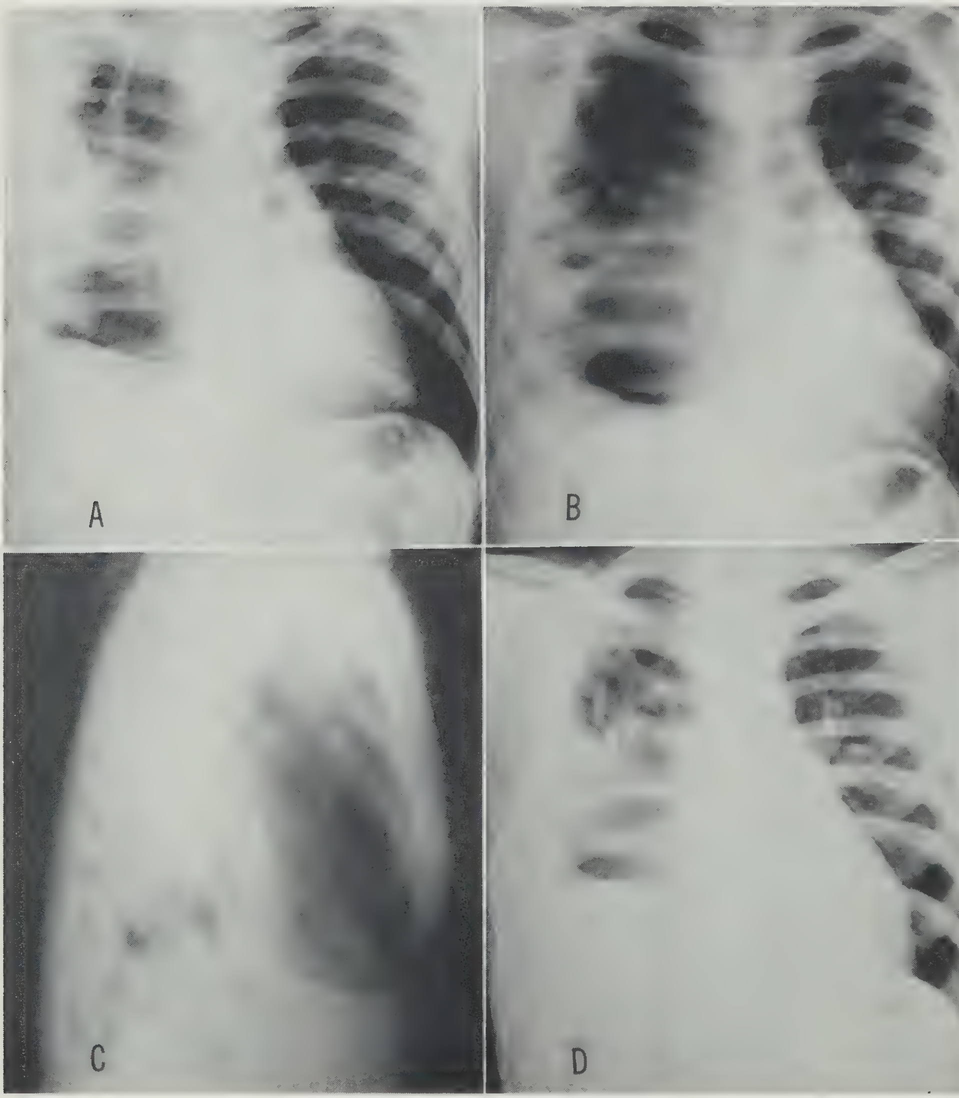

FIGURE 98.—Sucking wound of chest. A. Posteroanterior projection showing multiple fractures of ribs with hemopneumothorax. B. Posteroanterior projection 10 days later, showing large tension pneumothorax, with marked cardiac displacement to left. C. Lateral projection on same date, showing large pneumothoracic space anteriorly with atelectatic lung and thickened pleura posteriorly. D. Posteroanterior projection 3 weeks later, after decortication and wound closure.

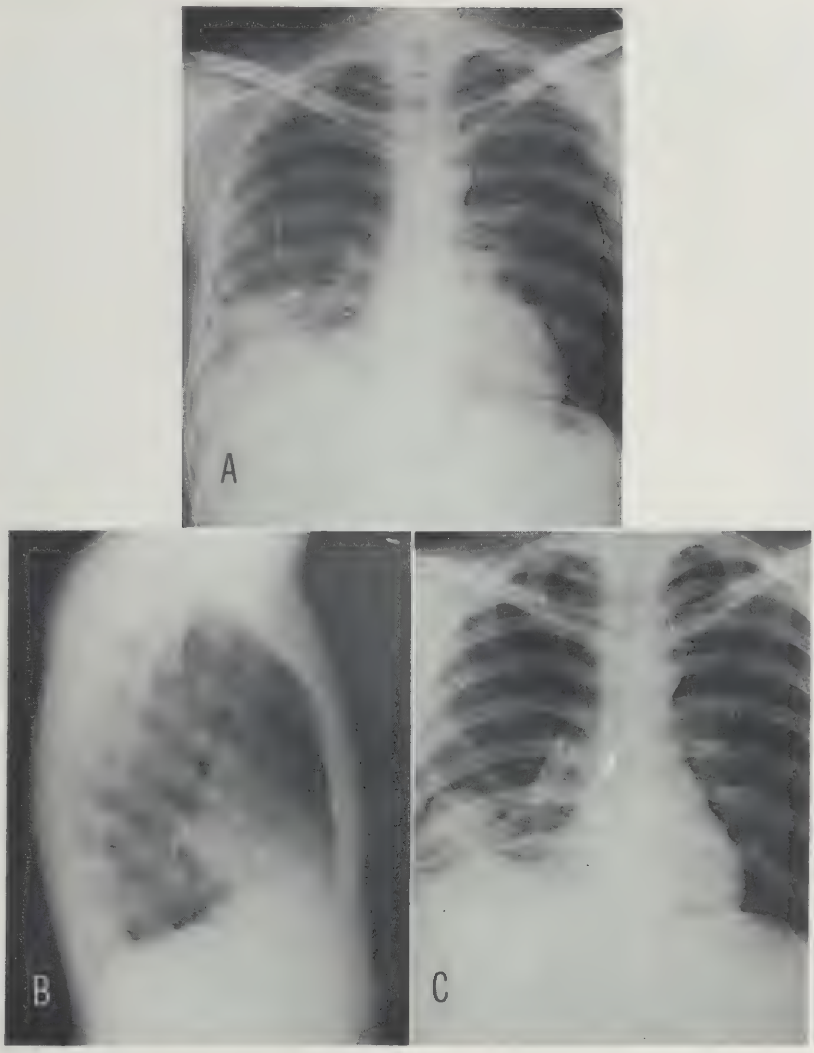

FIGURE 99.—Hemothorax. A. Posteroanterior projection of chest showing hematoma of right lower lobe with hemothorax and beginning clotting. B. Lateral projection localizing area in anterior basal segment of right lower lobe and interlobar area. C. Posteroanterior projection 7 days later. Note well-formed clot, which was subsequently removed at decortication.

chronic empyema, and by Delorme in 1894, for tuberculosis (*16*). The operation did not gain popularity then because of the high mortality associated with it, which was readily explained by the absence of the conditions which were so favorable in World War II, including competent anesthesia and the availability of whole blood.

The operation was first used in World War II in February 1943 in the

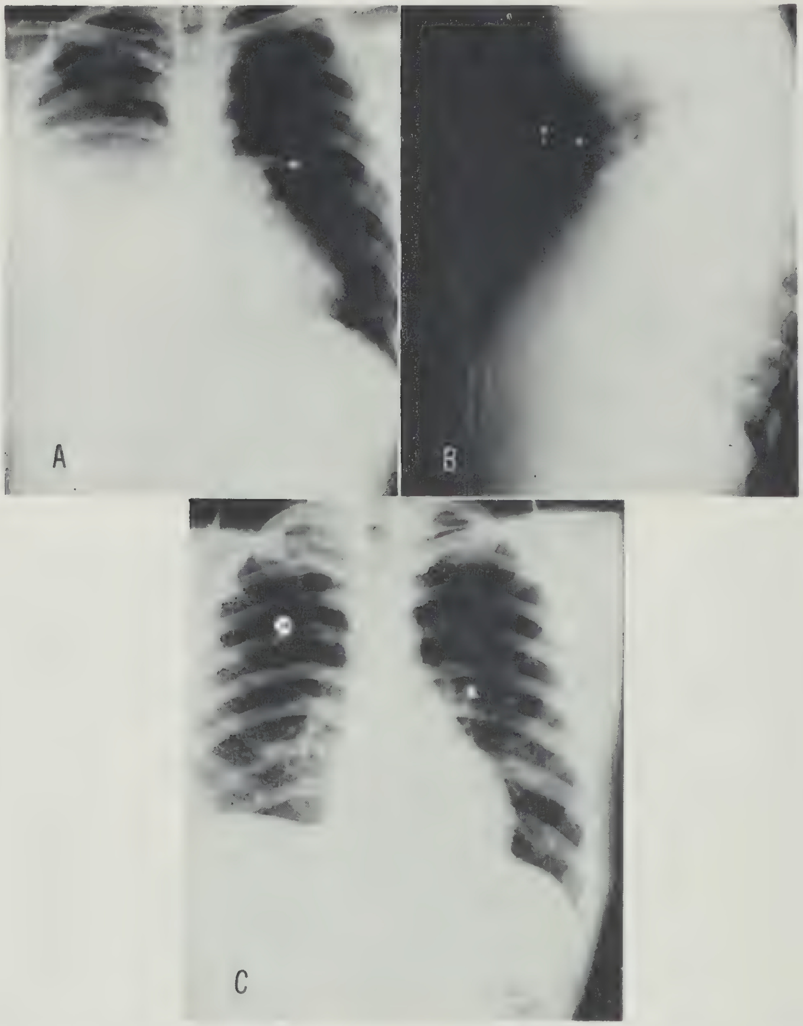

FIGURE 100.—Hemothorax. A. Posteroanterior projection showing right organized hemothorax, with marked pleural and pulmonary density. Small shell fragment traversed mediastinum to the left. B. Lateral projection showing massive triangular density posteriorly, representing thickened, organized hemothorax and infolded lung. C. Posteroanterior projection 6 weeks after decortication, showing absence of hemothorax and complete reinflation of lung.

North African theater by Maj. Thomas H. Burford, MC, at the 21st General Hospital at Bou Hanifia, Algeria (*16*, *17*). His results were excellent, and the information concerning the new technique was disseminated by the surgical consultant to other chest surgeons in the theater. It became immediately popular, and Major Burford's good results were widely duplicated. The

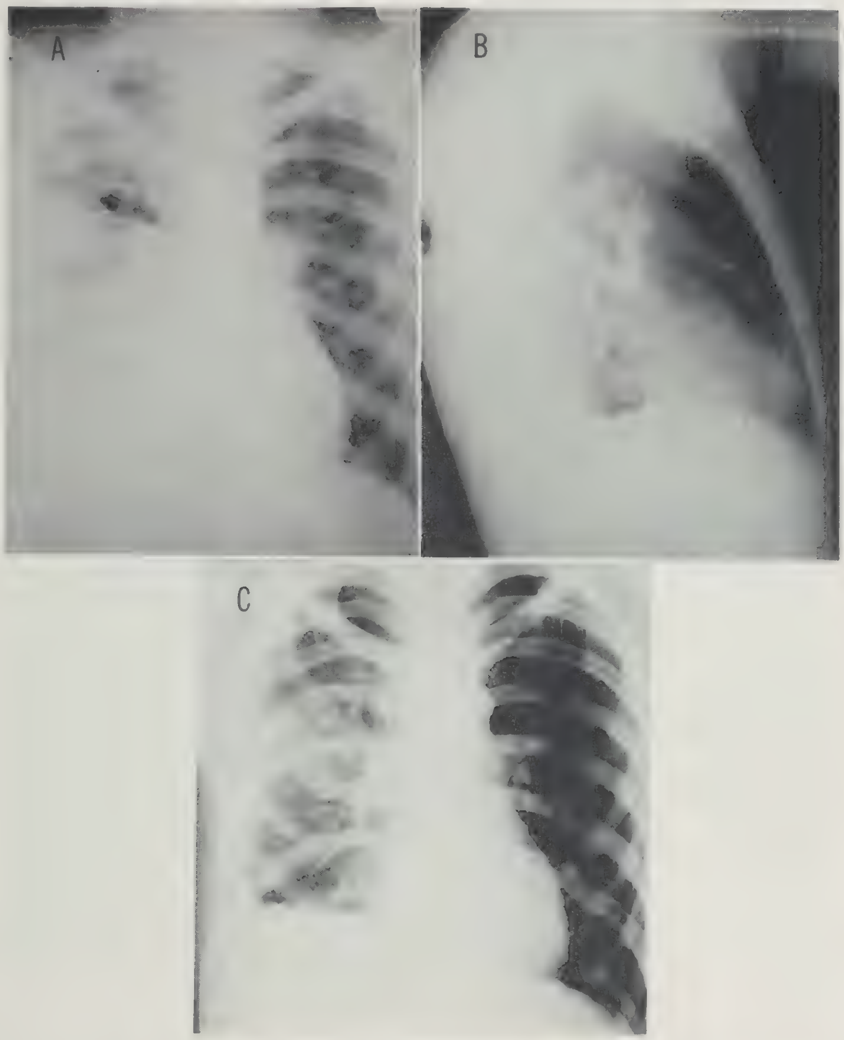

FIGURE 101.—Hemothorax. A. Posteroanterior projection of chest showing organizing hemothorax with small residual empyema pocket. Entire right pleural cavity seems to be involved. B. Lateral projection showing process limited to posterior area. Note triangular density. C. Posteroanterior projection 2 weeks after decortication. At this early postoperative stage reinflation is good with only limited residual pleural thickening.

establishment of chest centers in the theater permitted the concentration in them of experienced chest surgeons and of patients who needed the operation. In an analysis of 140 decortications for organizing hemothorax, Colonel Tuttle and his group reported good results in more than three-quarters of the cases and no deaths (*15*, *18*).

Decortication was subsequently extended to other types of closed patho-

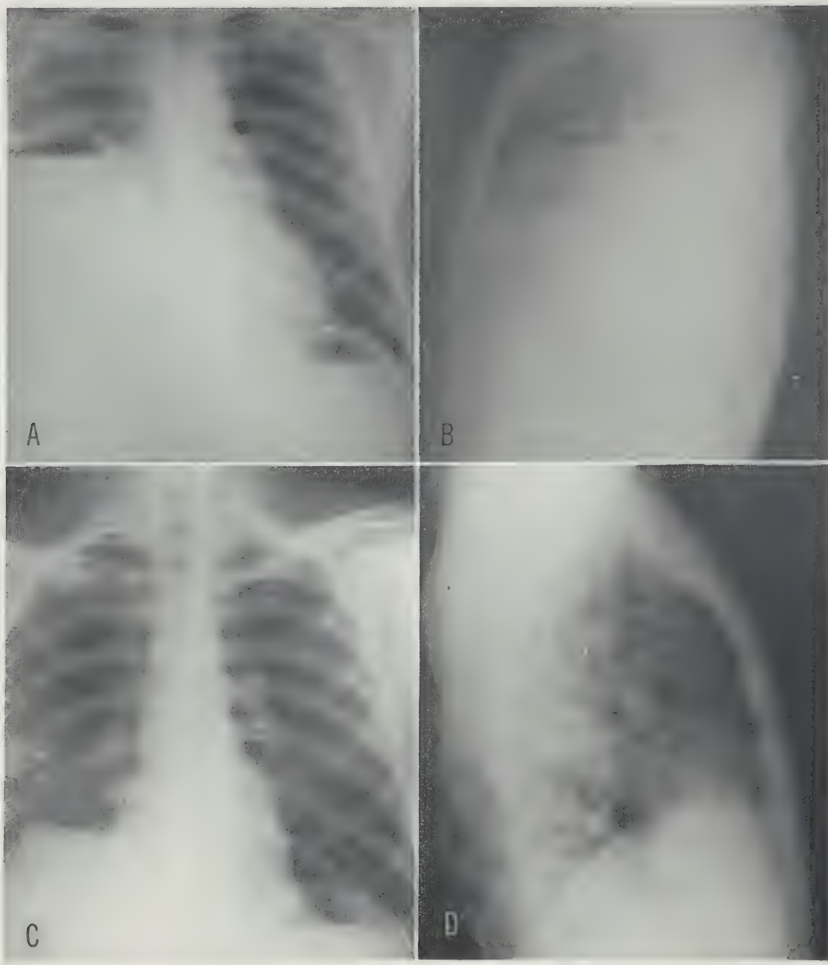

FIGURE 102.—Bile hemopneumothorax. A. Posteroanterior projection showing massive fluid collection, air fluid level, and shift of mediastinum to left. Missile penetrated margin of liver and diaphragm. B. Lateral projection showing massive fluid collection and fluid levels. C. Posteroanterior projection 6 weeks after decortication and wound closure. D. Lateral projection, same date.

logic processes, including pleuritis, organizing empyema, chronic empyema pockets with resulting residual pneumothorax spaces, and bile hemopneumothorax (fig. 102). In these conditions, just as in organizing hemothorax, the radiologist worked with the thoracic surgeon and played an important part in the comprehension and demonstration of the pathologic procedure and in the evolution of the corrective procedure.

Atelectasis.—Atelectasis, which was of frequent occurrence in war wounds, resembled the condition seen in civilian practice. It often appeared

FIGURE 103.—Atelectasis. A. Posteroanterior projection of chest showing atelectatic left lower lobe overlying cardiac margin, with slight elevation of left leaf of diaphragm, which is fixed, and left subdiaphragmatic abscess. B. Posteroanterior view 3 weeks later, after drainage of subphrenic abscess. Note reaeration of left lower lobe.

after extensive operations for thoracoabdominal wounds. It frequently was present in the lung overlying a subphrenic abscess (fig. 103). Plate or discoid atelectasis was also observed with other types of abdominal and subdiaphragmatic disease.

Bronchopleural fistula.—Bronchopleural fistulas were frequent in thoracic wounds, and the inevitable development of empyema made their identification necessary. This was usually accomplished by Lipiodol visualization.

THORACOABDOMINAL WOUNDS

The incidence of thoracoabdominal wounds was high. Their diagnosis was greatly simplified by roentgenologic examination, particularly in those cases in which a single shell fragment or bullet was the wounding agent and pulmonary and pleural reactions were absent. This type of injury had to be looked for in all chest roentgenograms on which hemothorax was evident. When the diagnosis was established, the transthoracic approach (another important development in the Mediterranean theater) was frequently used, and the radiologist's definition of the course of the missile was of great diagnostic help to the surgeon.

WOUNDS OF THE ABDOMEN

Foreign bodies penetrating the peritoneal cavity were ordinarily localized by means of anteroposterior and lateral roentgenograms supplemented

by fluoroscopy. Their precise localization was not important. Once the presence of a foreign body in the abdomen was established and the wound of entrance identified, the course of the object could be plotted and a reasonably accurate estimate made of the organ or organs involved. The mere presence of a foreign body in the peritoneal cavity was usually enough to make exploration mandatory. Most abdominal surgery was performed in forward hospitals, but most of the complications of these wounds were treated in fixed hospitals in the rear.

Extensive injuries were often encountered, including perforations of hollow viscera. The diagnosis was made by the roentgenologic demonstration of free air and the spillage of intestinal contents, manifested by fluid levels in the upright and decubitus positions.

An immediate complication of abdominal wounds, retroperitoneal hemorrhage, could often be diagnosed radiographically by obliteration of the demarcation of fascial planes and the presence of mottled densities within the retroperitoneal tissues.

Closed injuries of the abdomen did not differ from those encountered in civilian practice, though they were of greater frequency because of the occupational hazards of military life. Ruptures of the spleen, liver (fig. 104), kidneys, and bladder were observed most often. Ruptures of the small bowel and colon were occasionally encountered. Retroperitoneal rupture of the duodenum, with air distributed in the retroperitoneal space, was infrequent.

Complications

Paralytic ileus, whether dynamic or adynamic, was always a possibility. The multitude of possible etiologic factors present after extensive surgical procedures, and multiple areas of localized inflammation, made it more difficult to make a differential diagnosis than in civilian life. Postoperative ileus was well controlled by the routine use of gastrointestinal suction after abdominal surgery; its mortality was greatly reduced by prompt resort to the Miller-Abbott tube or some similar tube. The radiologist participated in the treatment of these conditions; his assistance was required in passing the tubes, and followup studies were always necessary (fig. 105).

Localized abscesses were diagnosed radiologically by the usual methods; that is, multiple projections in the supine, upright, and lateral decubitus, supplemented by fluoroscopy. Abscess pockets were often multiple; bilateral subphrenic abscesses, for instance, might be associated with other localized collections elsewhere in the peritoneal cavity (fig. 106). A frequent roentgenologic finding was atelectasis of the lower lobe of the ipsilateral lung associated with well-established subphrenic abscess. Specific localization of abscess pockets was essential for the surgeon in planning his approach for drainage (fig. 107).

Chronic fistulas originating in perforating wounds were investigated by whatever radiopaque material was available, including barium, sodium iodide,

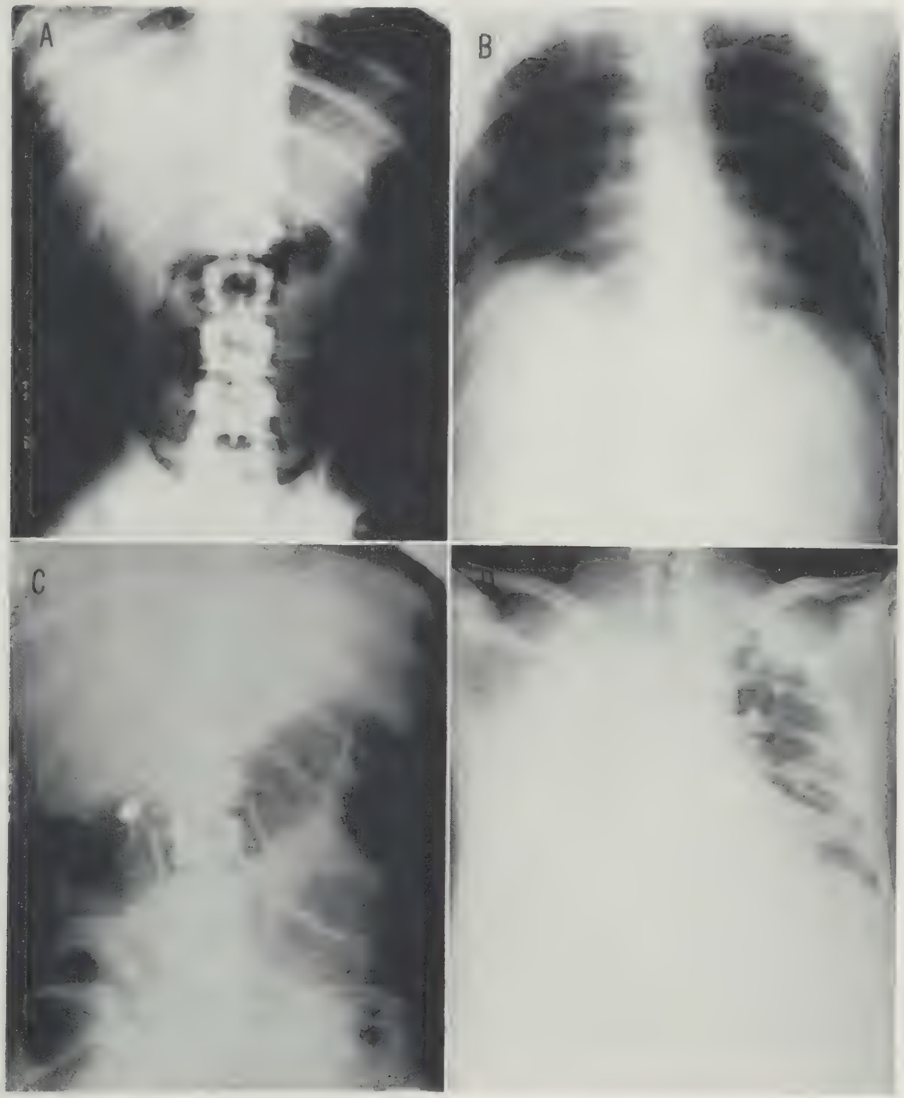

FIGURE 104.—Rupture of liver. A. Anteroposterior projection of abdomen, showing loss of distinction of right hepatic margin, apparent increase in size of hepatic mass, and elevation of right leaf of diaphragm. B. Anteroposterior roentgenogram of abdomen and chest, showing elevation of right leaf of diaphragm, motion of which was limited. Note that lungs are clear. C. Anteroposterior projection of abdomen 48 hours later, demonstrating moderate degree of adynamic ileus and further clouding of detail of abdominal structures. D. Posteroanterior roentgenogram of chest on same date, showing delayed right hemothorax.

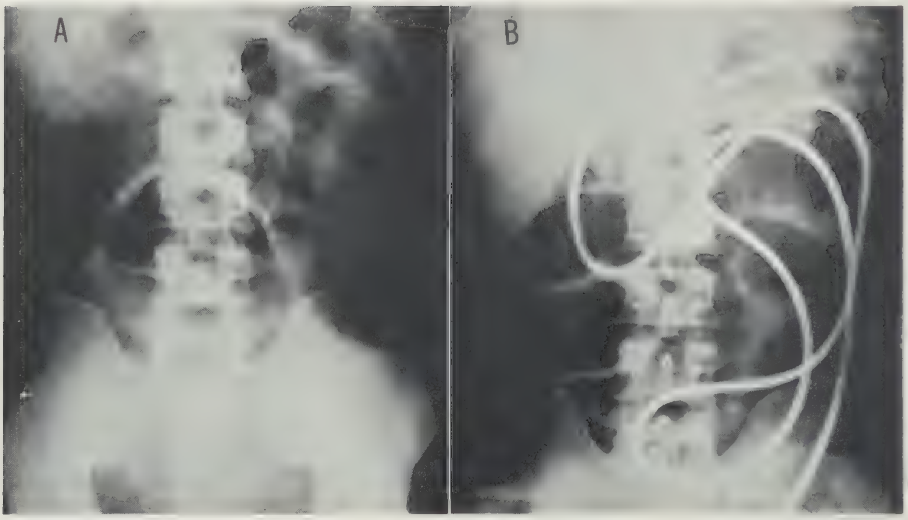

FIGURE 105.—Acute small bowel obstruction. A. Anteroposterior projection of abdomen showing extensive dilatation of loops of small bowel. B. Decompression of small bowel by Miller-Abbott tube. Some gas has passed into the colon.

Iodochlorol, Skiodan (mono-iodo-methane sulfonate of sodium), and Neo-iopax (sodium iodomethamate).

WOUNDS OF THE GENITOURINARY TRACT

Penetrating wounds of the urinary tract and closed trauma were investigated, as indicated, by cystography, urethrography, and intravenous and retrograde urography, though these refinements were not employed until routine plain studies had been made. When renal trauma was so severe that nephrectomy had to be considered, the adequacy of the contralateral kidney was investigated before surgery was undertaken.

Fistulas of the urinary tract were studied, like other fistulas, with whatever radiopaque media were available.

Noncombat Diseases and Conditions

THE SPINE

What came to be called "G.I. back" required studies of the lumbosacral region in many cases, but almost invariably there was no radiologic evidence of significant abnormalities. Extensive surveys were carried out in some hospitals in an attempt to correlate the clinical manifestations with congenital variations, lumbosacral angles, and other abnormalities; but the only finding of consequence was spondylolysis or spondylolisthesis. Many of these

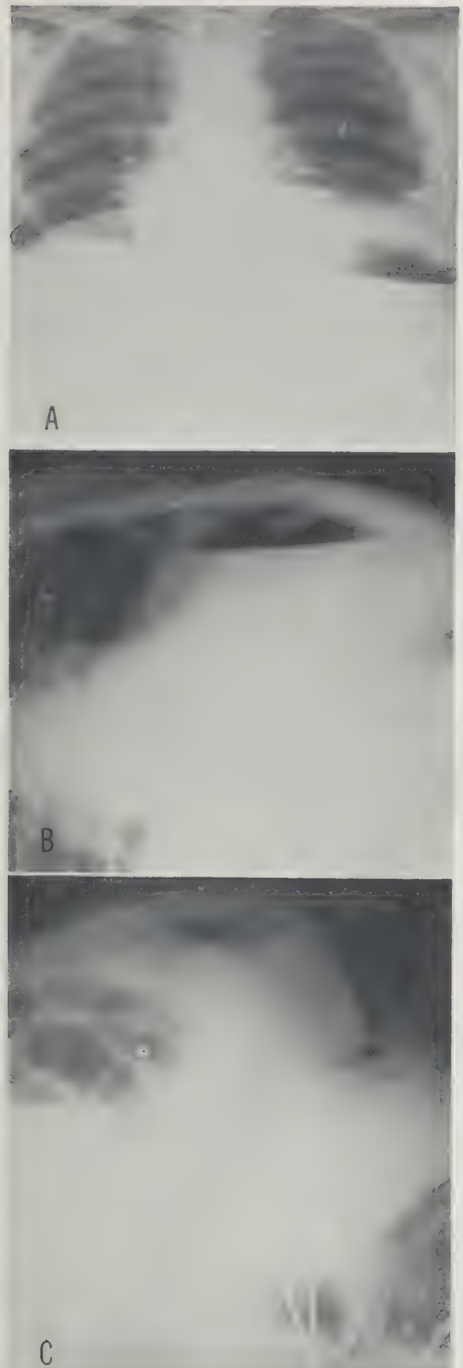

FIGURE 106.—Subdiaphragmatic abscess, multiple. A. Posteroanterior roentgenogram of chest of patient with penetrating wounds of abdomen, who had had severe septic course. Note left pleural effusion and large air collection beneath left leaf of diaphragm, which might, questionably, be in stomach. At fluoroscopy, both diaphragms were found fixed. B. Decubitus study, left side up, showing large collection beneath diaphragm, diagnosed as abscess pocket. Fluid flows freely in pleural cavity and migrates along mediastinal margin. C. Opposite decubitus study showing additional large inflammatory pocket containing air in right subphrenic region.

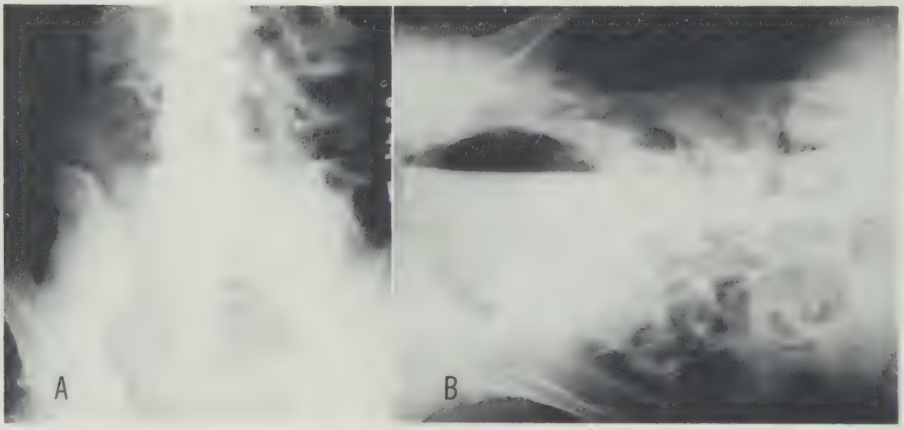

FIGURE 107.—Localization of intra-abdominal abscess. A. Anteroposterior projection of abdomen showing shell fragments and moderate ileus. Note vague outline of air pocket overlying sacrum. This patient had run a septic course. B. Decubitus film, right side up, demonstrating large air-fluid pocket in pelvic cavity and lower abdomen, representing localized collection. Air shadow in right flank is distended colon.

patients had no previous history of low back pain, but, under the circumstances of military life, decompensation occurred and caused pain; and sometimes a simple spondylolysis was converted to a spondylolisthesis (fig. 108).

Herniated nucleus pulposus could not be evaluated adequately by either neurosurgeons or radiologists in MTOUSA because of the unavailability of radiopaque media (*19*). Myelography with Lipiodol or Pantopaque (ethyl iodophenylundecylate) was a well-established diagnostic procedure in civilian practice before the war; it is not clear why provisions for it were not made in the Mediterranean theater. Possibly the explanation was fear that the procedure might be abused by those unaware of its potential risks and possible sequelae. As a result of this policy, intraluminal spinal abnormalities could be studied only by air myelography, a technique which had not proved especially useful in the hands of most radiologists and neurosurgeons and which did not prove very useful in military practice in the Mediterranean theater.

Patients suspected of suffering from ruptured disks were therefore managed on the basis of their clinical manifestations.

THE CHEST

Pneumonia.—All types of pneumonia were frequent, ranging from lesser degrees of bronchopneumonia to full-blown lobar pneumonia of pneumococcic origin. A few instances of Friedländer's pneumonia were encountered, but

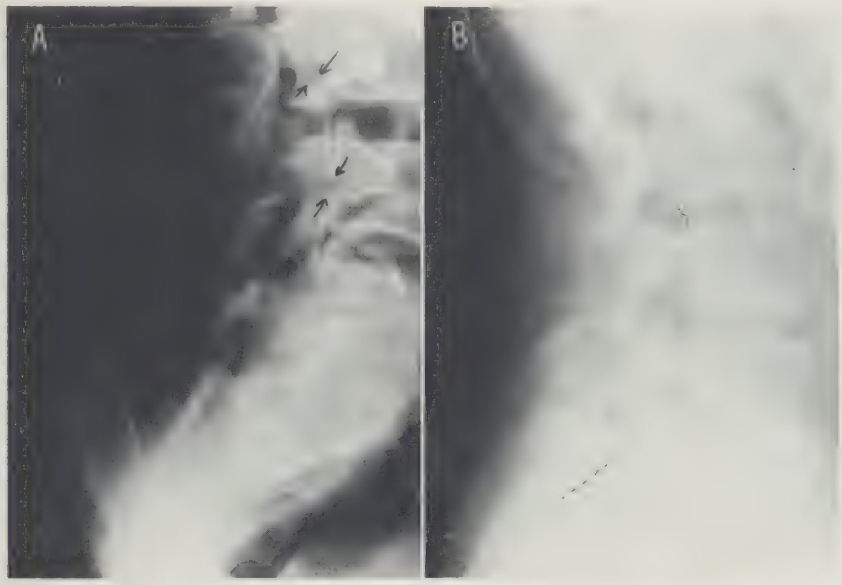

FIGURE 108.—Spondylolysis, spondylolisthesis. A. Upright roentgenogram showing bilateral defects at pars interarticularis of L_3 and L_4 due to spondylolysis. There is no spondylolisthesis. B. Upright roentgenogram showing spondylolisthesis, grade 2, L_5 on S_1. Degree of displacement is indicated by dotted lines. This patient had no symptoms referable to his back in civilian life or during the first 6 months of military service. Displacement was probably caused by lifting heavy weights.

the fulminating influenzal type of pneumonia that was so frequent and so fatal in World War I was very seldom observed (fig. 109).

Atypical pneumonias were frequently encountered; their myriad manifestations did as much as anything else to convince the clinician of the necessity and importance of complete and repeated roentgenologic studies. Each of the several epidemics of atypical pneumonia had its own characteristics. Oddly, in some instances the clinical reaction was severe and there was only minimal X-ray evidence of parenchymal disease (fig. 110).

In these virus lung infections, unresolved residual infiltrates tended to persist for long periods and were easily confused with the productive reinfection type of tuberculosis. It was the practice to hold patients with these conditions until roentgenograms showed complete resolution of all the infiltrates, which sometimes took as long as 3 months. Occasionally, under pressure of the military situation, these patients were reluctantly released earlier than was considered wise.

Tuberculosis.—Pulmonary tuberculosis was infrequent among U.S. troops, but when radiologic surveys were made of POW's, many instances of the disease were brought to light.

Infarction and embolism.—Pulmonary infarction was not often diag-

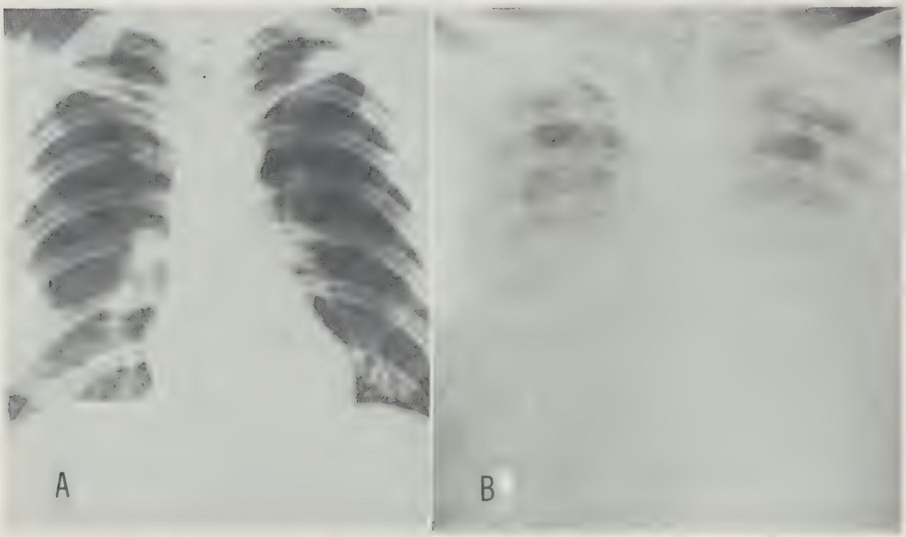

FIGURE 109.—Fulminating pneumonia. A. Posteroanterior projection of chest showing early parenchymal density in lower right lobe. Patient was critically ill clinically. B. Anteroposterior projection 3 days later. The patient died a few hours after this film was taken.

nosed in World War II. In the light of postwar knowledge, it may be that many instances of pneumonitis occurred on the basis of infarction. Certainly the extensive trauma and the potentialities for peripheral venous thrombosis that existed must have contributed more embolic and thrombotic phenomena in the lungs than were then recognized.

Embolic phenomena were fairly frequent. They resulted either in widespread focal disease or in solitary inflammatory processes that went on to abscess formation. Their frequency is not surprising in view of the numerous foci of infection that existed in many casualties, especially those with abdominal wounds (fig. 111).

Fungus infections.—Mycotic infections of various types were encountered, but no single type showed a high degree of frequency. They included aspergillosis, moniliasis, blastomycosis, and actinomycosis. One instance of actinomycotic abscess of the lung followed the drainage of a brain abscess of similar etiology. The lesion (fig. 112), which was undoubtedly of metastatic origin, was unusual in that the pleura was not involved. Only a few patients with coccidioidomycosis reached the theater, most of them having been filtered out in the Zone of Interior.

Malignant disease.—Carcinoma of the lung and mediastinum was infrequent, as would be expected in a population of the age of U.S. Army troops. Bronchogenic carcinoma presented with the usual radiologic findings of a solitary peripheral lesion; that is, an infiltrating peribronchial lesion at the root or an intraluminal obstructive lesion with associated atelectasis. Pri-

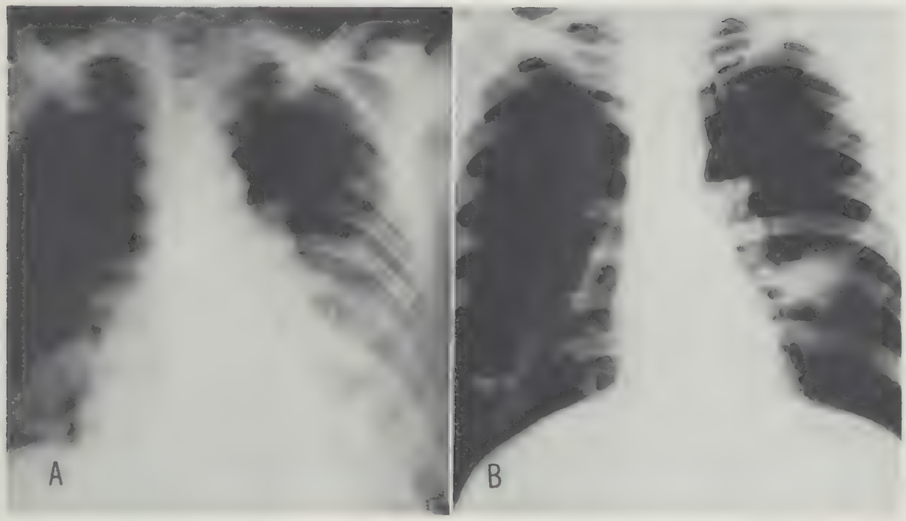

FIGURE 110.—Primary atypical pneumonia. A. Posteroanterior projection of chest, showing extensive bilateral infiltration and consolidation. In spite of extensive parenchymal involvement, symptomatology was minimal. B. Posteroanterior projection 3 weeks later, showing resolution of all disease except for lingular area and minimal density of left base. Lingular involvement was usually slow to resolve.

mary carcinomas were less frequent than neoplasms of the lymphoma group, which were usually detected on roentgenograms requested for the diagnosis of mediastinal or hilar masses.

Anomalies.—Congenital anomalies of the lung, heart, and great vessels were occasionally encountered in spite of the generally careful screening of all personnel accepted for active duty in the Army and especially of those designated for oversea duty. Several instances of coarctation of the aorta were observed in patients who shifted from a normotensive to a hypertensive state (fig. 113).

Other congenital lesions encountered in the cardiovascular system included right-sided aorta, abnormal origin of the subclavian artery, aneurysm of the pulmonary artery, poststenotic dilatation of the pulmonary artery, and hypoplastic aorta (fig. 114). A combat infantryman was observed who presented complete agenesis of the left lung, with the heart and mediastinum retracted posteromedially on the left and the entire thorax filled by the right lung. These findings were substantiated by bronchography (fig. 115). It is difficult to understand how a person with such anomalies went through all the preliminary stages of medical evaluation and was sent overseas without recognition of his condition.

Some congenital cysts were discovered when hemoptysis appeared, and an occasional case of congenital bronchiectasis was observed (figs. 116 and 117).

FIGURE 111.—Septic emboli. Posteroanterior projection of chest showing multiple areas of density, chiefly on left. Patient ran septic course with spiking fever following infection after abdominal wound.

Acquired cardiac disease.—Under the stress of military life, some men with subclinical heart lesions presented clinical manifestations of increasing hypertension and decompensation. A number of patients with early rheumatic heart disease and hypertension were therefore encountered. Pericardial effusion not associated with trauma usually resulted from rheumatic heart disease (fig. 118).

THE ABDOMEN

The intra-abdominal pathologic processes encountered by the radiologists in the Mediterranean theater covered all the diagnostic problems that would be expected in large numbers of men who were chiefly in the younger age group. The major problem was not clinical but technical: As already pointed out, the equipment provided by the T/E was usually of limited capacity and did not lend itself well to gastrointestinal work. Fluoroscopic devices, also as noted, were not those routinely available in civilian practice, and spot film mechanisms had to be improvised (p. 269). In spite of these handicaps, creditable work was accomplished in the diagnosis of peptic ulcer, gastritis, varying types of colitis, and disease of the small bowel. Almost all of this work was done in fixed installations.

Ruptured peptic ulcers were uncommon, probably because practically all of the ulcers encountered were of recent origin and were promptly investigated and treated.

Foreign bodies such as dentures, pins, and spoons were occasionally encountered in the stomach or the rectum, some accidentally or intentionally ingested and some deliberately introduced. Many of these patients, as might be expected, were under treatment on psychiatric wards.

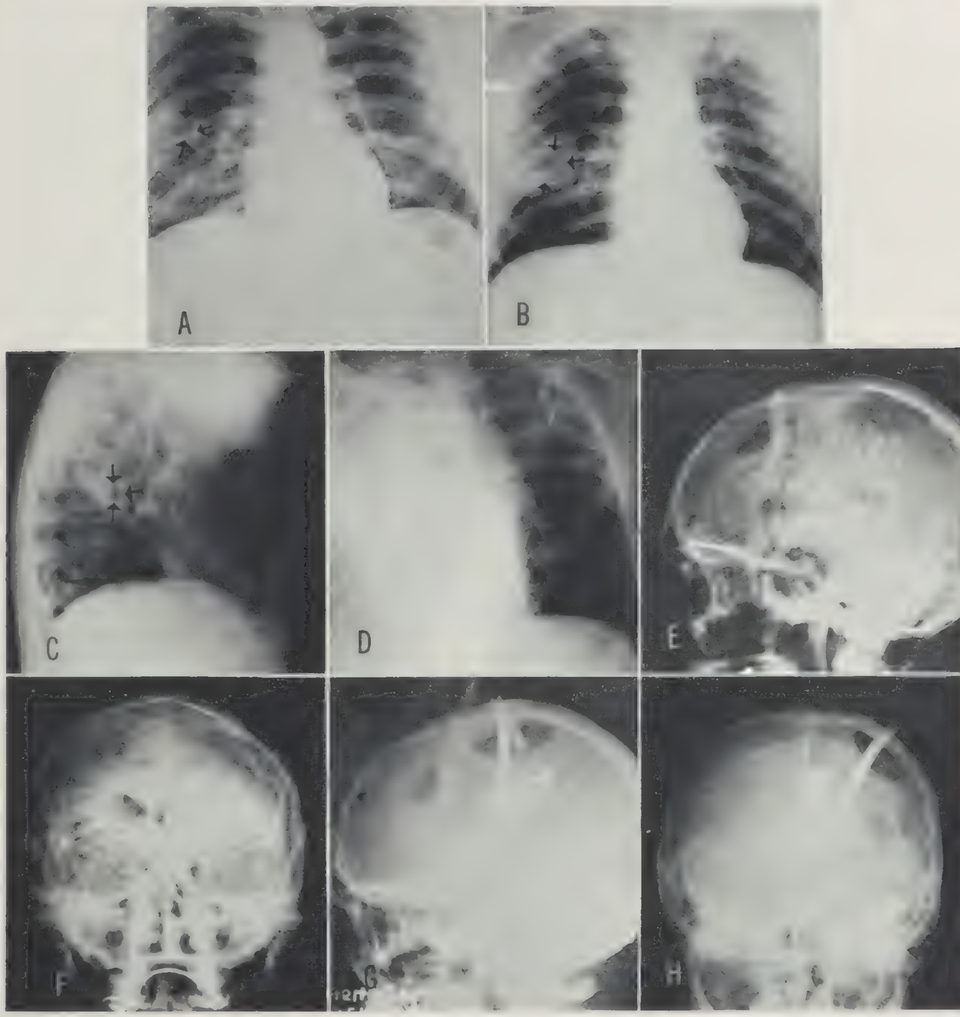

FIGURE 112.—Mycotic infection (actinomycosis). A. Posteroanterior projection of chest showing small cavity with surrounding exudate in right mid lung. Patient was admitted with low grade fever and severe headaches. B. Same, 7 days later, showing enlargement of cavity and of surrounding infiltrate, which is still well localized. Note absence of significant pleural involvement. C. Lateral projection of chest showing localization of small abscess cavity with surrounding infiltration in apical segment of right lower lobe. D. Posteroanterior projection of chest 7 days later. Massive atelectasis occurred as patient was being anesthetized for investigation of possible brain lesion. E. Lateral pneumoencephalogram showing invagination of lateral ventricle with marked pressure effects. F. Anteroposterior pneumoencephalogram showing marked displacement of ventricular system as result of massive lesion, presumably an abscess, in frontoparietal area. G. Lateral projection showing craniotomy defect with catheter extending into large, irregular abscess cavity, previously drained and injected with opaque medium. Diagnosis of actinomycosis had now been made, presumably metastatic from pulmonary lesion. H. Anteroposterior projection, same date, showing drainage tube and extent of intracerebral abscess.

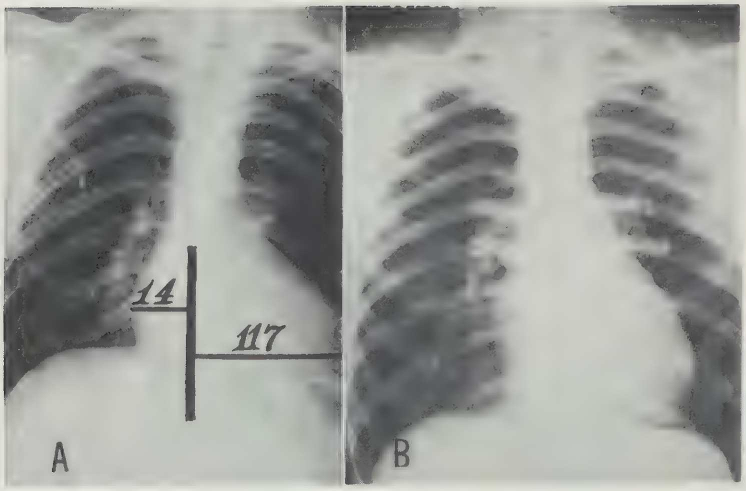

FIGURE 113.—Coarctation of aorta. A. Posteroanterior projection of chest showing moderate enlargement of left ventricle with hypoplastic aorta. Note notching of ribs, due to aortic coarctation. B. Posteroanterior projection of chest showing notching of ribs and some hyperplasia of aorta but no significant cardiac enlargement.

Small bowel disorders resulting from accentuated psychogenic stimuli were sometimes encountered, as were occasional instances of regional enteritis. Deficiency patterns were unusual. Other inflammatory diseases involving the small bowel were seen in numbers in released POW's. Extensive peritoneal and intestinal tuberculosis was seen in many of these patients.

The accidental radiologic discovery of *Ascaris lumbricoides* at the 36th General Hospital by Colonel Lofstrom and Captain Koch led them to check all subsequent studies of the small intestine from this standpoint. The result was the detection of five additional cases in 100 examinations of the small bowel (*20*). The diagnosis in each of the six cases was confirmed in the laboratory. None of the patients had a history of ascariasis or clinical manifestations pointing to the condition.

The characteristic finding (fig. 119) was the negative defects produced by the presence of the worms. These defects were observed in various portions of the small bowel from the upper jejunum to the lower ileum. In one case only one worm was detected, but in another six could be identified. They varied in size from 2 to 15 cm. None was detected by roentgenoscopy. The use of multiple hourly roentgenograms was found advantageous in verifying suggestive negative shadow defects. The 24-hour check did not reveal any residual barium in the intestinal tracts of the parasites.

The presence of the parasites had no effect on intestinal motility as reflected in the passage of the barium column. No noticeable changes were observed in the lumen of the intestine or the texture of the mucosal pattern. No irritability or spasm was demonstrable.

FIGURE 114.—Dilatation of pulmonary artery (aneurysm). Posteroanterior projection of chest, showing marked dilatation of pulmonary artery on left. Patient was asymptomatic. No murmurs were heard, and there were uniform average pulsations over the entire cardiac surface. The condition was considered an aneurysm of the pulmonary artery. Today (1963), such a patient could be studied by angiocardiography.

Fecal impaction was not uncommon, though it was a rather surprising condition in patients of this age group. Dehydration and the difficulty of maintaining regular bowel habits in combat situations were probably contributing factors. The diagnosis was made by the demonstrable fecal shadow in the rectal area combined with the distention of the proximal bowel observed on the roentgenograms.

THE URINARY TRACT

All types of urinary disorders common to patients chiefly of a young age group were encountered, with urinary calculi somewhat more frequent than would be expected in a similar civilian population. Peculiarities in location of service, type of activity, the mineral content of different water supplies, and dehydration were probably contributing factors. Tuberculosis, pyelonephritis, and hydronephrosis were seldom seen. Renal neoplasms were very infrequent, but testicular tumors were observed with comparative frequency, and surveys for possible extension of the disease were a radiologic responsibility.

All fixed U.S. Army hospitals were equipped with urologic tables with Bucky diaphragms. It was rather surprising to find such specialized equipment for the diagnosis of genitourinary pathologic conditions and so little consideration given to the provision of equipment for radiography of the heavy parts of the body.

Section V. Radiotherapy

The 17th General Hospital was selected as the radiation therapy center for the Peninsular Base Section for two reasons:

FIGURE 115.—Agenesis or congenital atelectasis of left lung. A. Posteroanterior projection of chest, taken routinely on patient (combat infantryman on full duty) admitted for injury of foot. Note retraction of mediastinal structures to left hemithorax. B. Lateral projection showing large radiolucent anterior window due to herniation of right lung to left, with posterior retraction of heart and mediastinal structures. C. Bronchogram showing complete obstruction of left main stem bronchus. Right bronchial tree is visualized and extends into entire left hemithorax. D. Oblique bronchogram showing distribution of right bronchi to right and left chest.

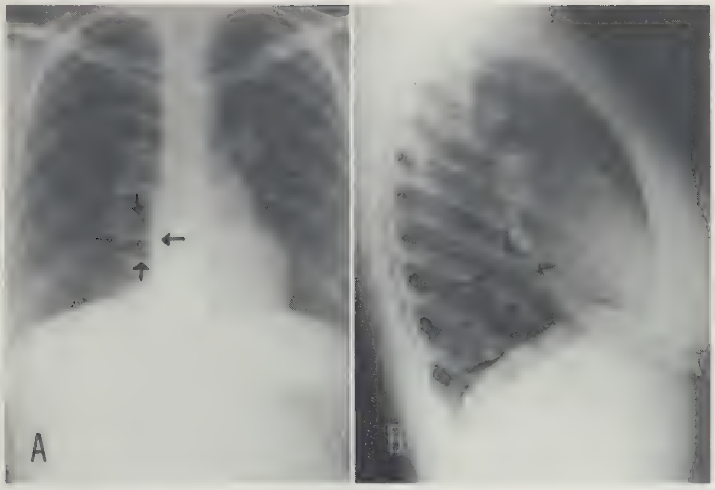

FIGURE 116.—Congenital cyst of lung. A. Posterior projection of chest, showing thin-walled cystic area below right hilum. Patient, a nurse, was admitted with slight hemoptysis and with no previous pulmonary history. B. Lateral projection showing outline of cyst in anterior segment of right lower lobe. Patient had no further symptoms during the year she remained under observation.

1. It had on its staff two officers certified in radiotherapy, Colonel Wilcox and Capt. William G. Belanger, MC.

2. It had moved into a large civilian hospital in Naples which had previously served as a civilian therapy center and which was equipped with three therapy units. One of the units was a Chaoul contact unit, one a superficial intermediate range unit, and one a deep therapy unit. These facilities made possible the treatment of such conditions as mediastinal lymphoma before the patients were evacuated to the Zone of Interior. Elective therapy was not administered routinely because of the desire to avoid conflict with the definitive therapy to be given in the United States. In spite of its limited use, however, elective therapy in these conditions proved an essential and valuable means of preparing certain patients for evacuation.

In 1944, the 17th General Hospital reported 1,120 superficial and 229 deep X-ray treatments.

The 46th General Hospital was designated as a center for superficial radiotherapy in the Mediterranean Base Section, and the 64th General Hospital was similarly designated in the Eastern Base Section. This arrangement permitted the close cooperation of the dermatologist and the radiologist and assured the best possible treatment for the patients.

Although the Picker field X-ray unit was designated for therapeutic use and the average output specified, only minimal dosages were used with it. Without a Victoreen r-meter in the theater, proper calibrations could not be effected, and only limited therapy was considered safe.

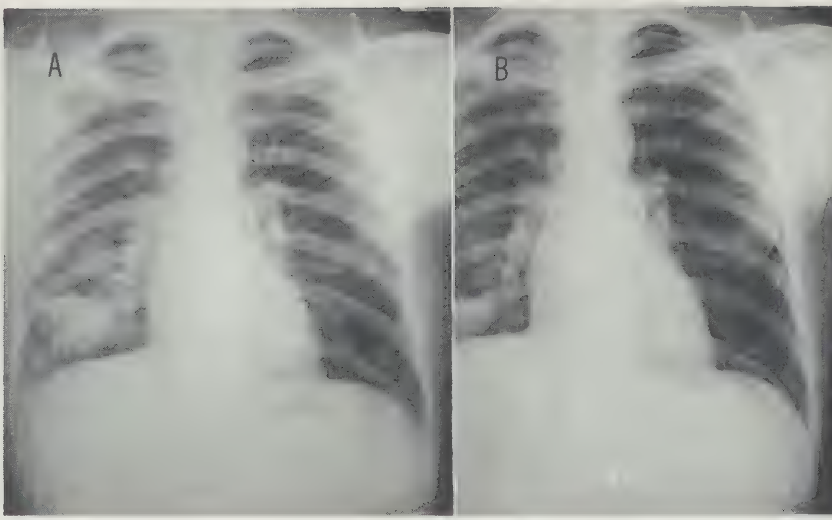

FIGURE 117.—Cyst of lung. A. Posteroanterior projection of chest showing localized rounded density in right lower lobe, with slightly visible air shadow above. Patient had experienced moderate hemoptysis but had no previous pulmonary history. B. Same, 7 days later. Moderate absorption of large clot within cyst has occurred.

Nonetheless, X-ray therapy was administered to a large number of patients with dermatologic conditions, especially, as in the European theater, plantar warts (p. 485). This condition was common and its manifestations were usually multiple. The frequency and extent of the condition could be explained by poor foot hygiene. In a few instances, the entire foot was cov-

FIGURE 118.—Pericardial effusion, rheumatic. Posteroanterior projection of chest showing marked cardiac enlargement. Pulsations were diminished over all borders. The condition cleared within 3 weeks on aspirin therapy.

FIGURE 119.—*Ascaris lumbricoides* of small bowel. A. Visualization of small bowel with barium, showing linear, rounded, negative defects of jejunum. Note absence of mucosal abnormalities. B. Magnified detail, localizing three distinct rounded worm shadows. C. Two of the largest round worms passed by patient after medical therapy.

ered to the level of the ankle with verrucous growths. Such patients, of course, had to be returned to the Zone of Interior.

In spite of the inadequate calibration of the equipment, complications of therapy were minimal. In fact, only one instance of radionecrosis was encountered—a lesion 3 cm. in diameter, in a patient on whom a large field had been treated in an attempt to control wart-formation over the lateral aspect of the os calcis. The absence of serious complications was explained by the limitations imposed by the theater surgeon, who permitted only qualified radiologists to administer radiotherapy.

In spite of the extensive damage caused by the wounding agents of World War II, early, complete debridement, with adjunct antibiotics, reduced the incidence of gas gangrene to negligible figures. None of it was treated by X-ray therapy.

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Part IV

EUROPEAN THEATER OF OPERATIONS

CHAPTER X

The Role of Consultants, General Functions and Special Problems[1]

Kenneth D. A. Allen, M.D.

THE CONSULTANT SYSTEM

The Professional Services Division set up in the Office of the Chief Surgeon, Headquarters, ETOUSA (European Theater of Operations, U.S. Army), in the summer of 1942 was composed of senior consultants in all major specialties. After their appointment, these consultants, with the approval of the Chief Surgeon, initiated all policies pertaining to specialized care and settled such problems concerned with their specialties as were referred to them for solution.

The services of the consultants were available as fully to the surgeons of the various armies as they were to the theater headquarters and in the hospitals to the rear. At no time during the active campaign, from a radiologic standpoint, were any difficulties encountered in coordinating the professional services of hospitals in forward and rear echelons.

In the fall of 1942, the Chief Surgeon, ETOUSA, Brig. Gen. (later Maj. Gen.) Paul R. Hawley, requested that The Surgeon General send him a senior consultant in radiology. When the consultant requested had not arrived by January 1943, General Hawley appointed Lt. Col. Robert Ball, MC, to function in this capacity, in addition to his duties as chief of the radiologic service, 2d General Hospital.[2]

Lt. Col. (later Col.) Kenneth D. A. Allen, MC (fig. 120), who had been sent from the Zone of Interior in response to General Hawley's request for a consultant in radiology, arrived in the European theater on 9 February

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[1] The details of the wartime experience in radiology in the European theater are contained in the official diary and the annual reports of the Senior Consultant in Radiology, ETOUSA (the author of this chapter), for 1943 (*1*), 1944 (*2*), and 1945 (*3*). At the end of the war, he prepared a final, comprehensive report on the total radiologic experience in this theater, including all essential clinical and administrative data (*4*). Unless otherwise indicated, the material in this section is derived from those reports, supplemented by certain additional data obtained from former medical officers during the course of the preparation of this history. All of the official reports just mentioned are on file, and available for consultation, in the General Reference and Research Branch, The Historical Unit, U.S. Army Medical Service, Walter Reed Army Medical Center, Forest Glen Section, Washington, D.C.

[2] Colonel Ball's report of his tour of duty as Acting Senior Consultant in Radiology, ETOUSA, is incorporated in the final report prepared by Colonel Allen on the radiologic experience in Europe at the end of the war in that theater.

FIGURE 120.—Col. Kenneth D. A. Allen, MC, Senior Consultant in Radiology, ETOUSA, 1943–45.

1943 and was appointed Senior Consultant in Radiology, ETOUSA, on 16 February 1943.[3]

Radiology in World War II, like all other specialties, owes a great deal to General Hawley. It was his dedication to, and understanding of, the physical welfare of the soldier that inspired him to secure a modification of the Army table of organization to provide consultants in the various specialties. His profound knowledge of all specialties was a constant source of amazement to the consultants in these specialties. One illustration of his uncanny knowledge and ability was his immediate decision, in the fall of 1942, to purchase in the United Kingdom the X-ray machines which he had learned could not be procured from the United States (p. 367). He was obliged to take action himself because the consultant in radiology whom he had requested had not yet arrived. His choice of the types of machines to be purchased was also excellent.

FUNCTIONS OF THE SENIOR CONSULTANT IN RADIOLOGY

Immediately after his arrival in the European theater, Colonel Allen proceeded to assume his responsibilities under the verbal orders, and on the

[3] Colonel Allen was well qualified for the responsibilities he was undertaking. Before the war, he had served as Director, X-Ray Department, Denver General Hospital and was also radiologist at the Presbyterian, St. Luke's, and Children's Hospitals, Denver, Colo. In 1953, the Society of ETO Radiologists, meeting in Chicago, presented a plaque to Colonel Allen (p. 126) "in recognition and appreciation of his unselfish service" as Senior Consultant in Radiology in the European theater.—A. L. A.

instructions, of the theater chief surgeon, delivered through the Chief, Professional Services Division, Col. James C. Kimbrough, MC. Colonel Kimbrough's orders were general and all-embracing: "Your duty is to furnish good radiologic service to the U.S. Army in the ETO."

Colonel Allen had very little to guide him. Radiology in World War I, even though there had been a consultant in the specialty in the European theater (p. 5), was very different from radiology in World War II. Moreover, in the 25 years preceding the Second World War, this specialty probably underwent more changes than any other in the whole field of medicine.

For these and other reasons, it was clear that the provision of adequate centralized control of the radiologic service of an expeditionary force numbered in the millions would, especially in the forward echelon, place heavy administrative as well as professional responsibilities upon the Senior Consultant in Radiology, ETOUSA. There were new and complex problems immediately evident, many of which had been overlooked in earlier planning.

To determine what his functions should be and to decide upon a course of action to meet the problems of this specialty, Colonel Allen made a survey of the current status of radiology in the theater. He also secured such information as he could concerning the probable expansion of the Armed Forces, in order to correlate the necessary expansion of radiologic services with it. At the conclusion of this survey, it seemed to him that his duties would be chiefly advisory and would fall into the following categories:

1. Advice on personnel (including professional qualifications of radiologists and radiologic technicians), their proved ability, their assignment, and their orientation and refresher training.
2. Advice on equipment (including selection of types, procurement, and tables of basic allowances) for general, station, evacuation, and field hospitals and for dispensaries.
3. Advice on protection against radiation of X-ray personnel.
4. Advice on planning for radiologic services in forward and rear areas to parallel surgical arrangements in preparation for the invasion of the Continent.
5. Supervision of X-ray therapy.
6. Professional support of radiologists.
7. Liaison with the radiologic service of the British and other Allied armies.

The foregoing summary suggests, as already intimated, that at this time the Senior Consultant in Radiology, ETOUSA, was taking it for granted that his duties would be largely advisory. The facts proved to be quite different. In spite of wholehearted support everywhere in the theater, the implementation of much of his advice proved to be his responsibility also.[4] One reason for this situation was the repeated development of unforeseen circumstances. When, for instance, it was found that mobile X-ray units would be necessary to amplify the radiologic services provided by overburdened units in forward areas (p. 405), Colonel Allen not only had to supervise their design but also had to deal personally with the various services

[4] In retrospect, it seems that all the professional advisers of the theater chief surgeon might better have been called directors of their various specialties rather than consultants, since the latter term fails to indicate that they had administrative and executive, as well as consultative, functions.

which would procure the equipment, construct the units, and provide personnel for construction and field testing. It should be emphasized again that the spirit of cooperation on the parts of all concerned greatly simplified this work. The cooperation of the Finance and Supply Division, Office of the Chief Surgeon, Headquarters, ETOUSA, was particularly notable.

The various functions just outlined are discussed in detail in this and the following chapters.

REGIONAL CONSULTANTS

Appointment

By the spring of 1943, well over a year before the invasion of the Continent, it had become evident that the number of hospitals in the European theater was already so large that the supervision of their X-ray departments by a single consultant was no longer practical. The Professional Services Division, Office of the Chief Surgeon, ETOUSA, recognized this situation in all the specialties, and General Hawley approved the appointment of regional consultants, who would add their consultant duties to their duties as chiefs of the X-ray and other departments in their various hospitals.

In recommending medical officers for appointment as regional consultants, Colonel Allen took into account not only their professional ability and experience but also their adaptability to wartime conditions, their initiative, and their qualities of tact, diplomacy, and leadership. The following officers were appointed regional consultants in radiology in Circular Letter No. 98, issued 30 May 1943 (*5*): Lt. Col. (later Col.) Magnus I. Smedal, MC, 5th General Hospital; Lt. Col. Foster C. Rulison, MC, 52d General Hospital; Maj. (later Lt. Col.) Earl H. Gray, MC, 30th General Hospital; Maj. (later Col.) Jack Spencer, MC, 67th General Hospital; and Capt. (later Lt. Col.) Frank M. Windrow, 298th General Hospital.

In February 1944, two additional regional consultants were appointed, Lt. Col. (later Col.) Gibbons W. Murphy, MC, 65th General Hospital, and Maj. (later Lt. Col.) James B. Hall, MC, 58th General Hospital. These final appointments provided for a regional consultant in radiology in each hospital center in the United Kingdom.

After the invasion of the Continent and the resulting expansion of medical activities, the use of regional consultants was extended correspondingly. In a letter to General Hawley dated 24 October 1944, Colonel Allen listed the current assignments of regional consultants to base sections as follows:

Loire, Lt. Col. (later Col.) George Gamsu, MC, 19th General Hospital.

Normandy, Lt. Col. (later Col.) Earl H. Gray, MC, 30th General Hospital; Lt. Col. (later Col.) Magnus I. Smedal, MC, 5th General Hospital.

Seine, Lt. Col. Alfred C. Ledoux, MC, 108th General Hospital.

Channel, Capt. Chester P. Widmeyer, MC, temporary.

Oise, Maj. (later Lt. Col.) Rolfe M. Harvey, MC, temporary.

ADSEC (Advanced Section), Lt. Col. Frank M. Windrow, MC, 298th General Hospital.

United Kingdom, Lt. Col. Joseph C. Rude, MC, 131st General Hospital; Lt. Col. Foster C. Rulison, MC, 52d General Hospital; Lt. Col. (later Col.) Jack Spencer, MC, 67th General Hospital; Lt. Col. (later Col.) Gibbons W. Murphy, MC, 65th General Hospital; Lt. Col. (later Col.) Elmer A. Lodmell, MC, 103d General Hospital; Maj. (later Lt. Col.) Bernhardt I. Wulff, MC, 83d General Hospital; and Maj. (later Lt. Col.) Charles W. Anderson, MC, 192d General Hospital.

The appointment of two more regional consultants on the Continent early in 1945 for the Brittany and Delta base sections provided consultant personnel for all nine base sections.

Functions

As the theater expanded, the responsibilities and usefulness of the regional consultants, both in the United Kingdom and on the Continent, increased proportionately. The duties of those in the United Kingdom became especially important after October 1944, when the Professional Services Division, Office of the Chief Surgeon, ETOUSA, moved to Paris and the Senior Consultant in Radiology found himself increasingly occupied with his duties on the Continent.

In essence, the duties of the regional consultants resembled those of the Senior Consultant in Radiology. They made periodic visits to general and station hospitals in their prescribed territories in the United Kingdom and, later, to the hospitals in these categories and to evacuation hospitals on the Continent. After inspecting the services and advising the radiologists at the various installations, they reported to the Senior Consultant in Radiology, ETOUSA, and made recommendations to him.

During 1943 and early 1944, the regional consultants attended periodic meetings conducted by the senior consultant, at which they formulated plans and policies for the invasion of the Continent and discussed their other problems. After the Professional Services Division was moved to Paris, it was possible for the senior consultant to preside over only one such meeting, though he made frequent visits to the Office of the Base Surgeon in the United Kingdom and met the regional consultants in radiology in that section, as well as the Consultant in Surgery, United Kingdom Base Section.

Regional consultants had to deal with problems of an administrative and military nature as well as with professional problems. They concerned themselves with the following matters:

1. It was especially important for them to orient newly arrived radiologists in administrative duties and to assist them in establishing a system for handling patients, radiographs, and reports within the hospital during sudden, heavy loads. Without such a system, the X-ray department could readily form a bottleneck in both the surgical care and the evacuation of casualties.

2. Regional consultants aided new radiologists in organizing an instructional program for technicians that would provide them with training in both professional work and military discipline.

3. They were especially helpful in securing the transfer of radiographs with patients (p. 340).

4. They assisted the senior consultant in recommending radiologic personnel for transfer.

5. They also assisted him in maintaining a high standard of radiography and in correlating radiology with other specialties.

6. They were useful, indirectly, in supporting the morale of radiologists.

In addition to these functions, regional consultants were authorized to recommend temporary duty assignments of radiologists within a group or center, in order to equalize radiologic work when one or more of the hospitals seemed overburdened with casualties. They designated the particular radiologist to serve when one was required for detached service outside the center or had to be replaced because of illness. Requests made to a center for the names of enlisted or officer personnel to fill quotas for attendance at radiologic conferences and courses of instruction were usually referred to the regional consultants for implementation.

COORDINATORS

Because it is admittedly difficult for a radiologist who sees only his own radiographs to maintain an optimum quality of radiography, the Senior Consultant in Radiology, ETOUSA, advised the use of radiologic coordinators for each Army. The idea was that these officers would have the opportunity to compare radiographic quality in many departments and could make suggestions for improvement to radiologists whose production was found to be below standard.

In the First and the Third U.S. Army, radiologists were appointed from evacuation hospitals to coordinate the X-ray activities of the army while at the same time they continued their regular duties. For a time, the First U.S. Army had a full-time coordinator in the person of Colonel Lodmell.

These coordinators, who were appointed in September, October, and November 1944, performed four useful functions:

1. They carried from department to department information about procedures and improvisations which had proved useful.

2. They appraised the quality of radiography and interpretation, both absolutely and comparatively.

3. They promoted radiologic conferences, especially during rest periods.

4. They established uniform policies for the custody of radiographs.

In retrospect, it seems that a good future source of coordinators would be the X-ray teams of auxiliary surgical groups provided for in T/O & E 8–500, 18 June 1945, because these teams moved from hospital to hospital.

LIAISON WITH BRITISH RADIOLOGISTS

In February 1943, shortly after his arrival in the European theater, Colonel Allen was advised to call upon Brigadier D. B. McGrigor, RAMC,

FIGURE 121.—Brigadier D. B. McGrigor, RAMC (center), in conference with Col. Kenneth D. A. Allen, MC, Senior Consultant in Radiology, ETOUSA (left), and Col. Elliott C. Cutler, MC, Senior Consultant in Surgery, ETOUSA, in the spring of 1944.

Chief Consultant in Radiology to the British Army. The first visit to him, on 26 March 1943, was followed by many and frequent conferences (fig. 121) that resulted in the exchange of information and facilities between the two medical services and in great benefit to the U.S. Army radiologic service.

During March, April, and May of 1943, contacts were also made with Prof. D. W. Windeyer, Director, Middlesex and Mount Vernon Hospitals, London, and Dr. Ralston Paterson, Director, Therapeutic Radiology, Christie Hospital, Manchester. Other contacts were made with Dr. A. E. Barclay, Consulting Advisor in Radiology to the British Ministry of Health, who was Director, X-Ray Research, Nuffield Institute, Oxford; Lt. Col. R. Boulton Myles, RAMC, Commanding Officer, Royal Army Medical College X-Ray School; Lt. Col. Eric Samuel, RAMC, Colonel Myles' deputy; and Dr. R. E. Roberts, Liverpool, Honorary Civilian Consultant in Radiology to the British Army in the United Kingdom. Still later, conferences were held with Prof. W. V. Mayneord, Professor of Physics, University of London, and perhaps the leading X-ray physicist in Great Britain.

Exchange of Services

Liaison with these British radiologists (fig. 122) contributed inestimably to the comfort and welfare of U.S. soldiers. They gave unstintingly of their

FIGURE 122.—Distinguished British radiologists whose cooperation and assistance augmented the U.S. war effort. Left to right, front row: Col. Kenneth D. A. Allen, Senior Consultant in Radiology, U.S. Army; Dr. R. E. Roberts, Honorary Consultant to the British Army at Home; Brigadier D. B. McGrigor, Consulting Radiologist to the British Army; and Dr. A. E. Barclay, Consulting Advisor in Radiology to the British Ministry of Health. Back row: Maj. J. Duncan White, Officer in Charge of Mass Miniature Radiography; Prof. W. V. Mayneord, Professor of Physics, University of London; Lt. Col. R. Boulton Myles, Commanding Officer of the Royal Army Medical College X-Ray School; Capt. Norman Booker, X-Ray Service Officer; and Maj. T. A. Brocklebank, representing radiologists on service abroad.

facilities, their time, and their vast knowledge and experience. There were numerous illustrations of these benefits. Among them were the provision of X-ray therapy in civilian British centers for U.S. soldiers (p. 485); the procurement of British X-ray equipment for U.S. hospitals (p. 367); and training programs in British hospitals and at the Royal Army Medical College X-Ray School for U.S. radiologists (p. 353) and X-ray technicians (p. 362).

Testimony of the valuable assistance rendered to the radiologic service in the U.S. Army by British radiologists is evident in the award of the Legion of Merit to Brigadier McGrigor and of the Bronze Star Medal to his deputy, Colonel Samuel. The letter which General Hawley wrote on 11 May 1945 to the British radiologists [5] who had assisted in the U.S. radiology program is

[5] Dr. Paterson, Christie Hospital, Manchester, Lancs.; Dr. Ffrancon Roberts, Douty Clinic, Addenbrooks Hospital, Cambridge; Dr. Byron Adams, The General Hospital, Bristol, Somerset; and Professor Windeyer, Middlesex Hospital, London.

further evidence of U.S. appreciation. It read as follows:

> For 2 years you have been administering X-ray therapy to American troops of the U.S. Army. Many scores have been benefited, comforted, and returned to duty by your expert care.
>
> I, personally, know that the care given our soldiers has been at times a heavy load when added to your otherwise arduous duties, and I know that you cheerfully and unhesitatingly accepted the responsibility entirely voluntarily when the request was made by our Senior Consultant in Radiology.
>
> On behalf of the U.S. Army and Medical Corps, I thank you for your great service.

The benefits of this liaison were not, of course, all confined to the U.S. radiologic service. The British themselves derived both direct and indirect benefit from it. The U.S. Army, for instance, for more than a year furnished radiologic service at one Emergency Medical Service hospital, and on several other occasions, it provided full-time service for 30 days or more at other British hospitals.

Maj. (later Lt. Col.) Linneus G. Idstrom, MC, radiologist at the 116th General Hospital, demonstrated the miniature X-ray machine he had devised for training purposes (p. 362) to the faculty of radiology at the British Institute of Radiology. The British appreciation of this demonstration was expressed in the following letter, dated 10 July 1945, from the president of the institute, Dr. Paterson, to the Senior Consultant in Radiology:

> As you are probably aware, your Army went to a very considerable amount of trouble to allow Lieutenant Colonel Idstrom to attend our Leeds Annual Conference for a Demonstration. He put up an amazingly interesting show, of which he can well be proud and indeed you can be proud of what was a genuine addition to the programme of the meeting.
>
> Would you convey to the necessary authorities my very best thanks for all that was done?

Combined Meetings

U.S. Army radiologic officers were invited to attend the 1943, 1944, and 1945 annual meetings of the radiologists of the British Army and of the Emergency Medical Service of Great Britain. At these meetings radiologic procedures and developments were reviewed and ideas were exchanged. At the last of these meetings, held on 16 July 1945, the experience in the European theater of the British organizations and the U.S. Army was pooled. The reports and recommendations, which were prepared before the meeting, exhibited little that was controversial in principle. The U.S. Army advocated radiologic service somewhat farther forward than the British, who agreed in principle, however, with the increased mobility provided in forward areas by the teams and equipment of the U.S. Army mobile X-ray units and auxiliary surgical group teams.

Tours of Hospitals

In December 1944, Brigadier McGrigor accompanied the Senior Consultant in Radiology, ETOUSA, on a 960-mile tour of many front and rear U.S. Army hospitals. In the course of the trip, British hospitals on the Continent

were also visited. Ample opportunities were thus afforded for comparison and criticism of the radiologic services of both Armies, as well as for interesting and exciting experiences.

The contacts with Brigadier McGrigor were particularly rewarding. Thoroughly British in every respect, and a most dignified person, he was readily adaptable to all circumstances, as evidenced by his willingness to ride in a jeep and his fondness for U.S. Army K rations. Brigadier McGrigor had repeatedly requested permission to visit British frontlines, to offer advice concerning radiology there, but had repeatedly been refused. The arrangement that permitted him to make the tour with the U.S. Army Senior Consultant in Radiology was the solution of this particular problem; he was correct in his belief that the problems of frontline radiology in both Armies would be very similar.

On one occasion, Brigadier McGrigor, Colonel Allen, and their 6-foot driver were halted at a railroad crossing by the French woman guard. The Brigadier spoke no French, so the senior consultant, of necessity, employed his own halting and inadequate ability in that language to try to convince her that they should be allowed to cross the tracks. She was adamant in her refusal; she had lowered the guard rails and she refused to raise them because, she said, a train was due any minute. A tedious wait was punctuated by frequent fruitless attempts to get her to change her mind. When the train had finally come and gone, the jeep passengers realized that the detonation they had just heard and the smoke they were observing was from an enemy buzz bomb which had exploded exactly at the point at which they would have crossed the tracks if they had been permitted to proceed as they wished.

A similar near-catastrophe was averted by a U.S. Army guard who refused to allow Brigadier McGrigor and Colonel Allen to proceed to the last hospital they had planned to inspect. He softened somewhat at the sight of the Brigadier, who decided, however, to cancel the visit. It was later learned that the hospital was in the hands of the Germans.

PROTECTION OF RADIOLOGIC PERSONNEL

Development of Building Practices

In March 1943, the Construction Section, Hospitalization Division, Office of the Chief Surgeon, ETOUSA, directed the attention of the Senior Consultant in Radiology to the resistant attitude assumed by U.S. engineers to the provision of adequate X-ray protection in hospitals then under construction. The information induced Colonel Allen, in view of current and pending construction of hospital buildings, to give first priority to this problem over other pressing problems. In April 1943, after a survey of the X-ray departments of fixed hospitals in the United Kingdom, he established the policy that X-ray protection of technicians and radiologists should be as thorough in fixed X-ray facilities in the European theater as it was in civilian institu-

tions in the United States, and that X-ray departments in forward hospitals should approach this ideal as far as possible.

The resistant attitude assumed by U.S. engineers was derived from British engineers, who took the position that no lead or barium protection was necessary for technicians other than that built in the tube head, to stop direct radiation from the tube. The varying standards of construction were a matter of utmost importance to the U.S. Army, since the British were doing the actual building of U.S. Army hospitals in the United Kingdom.

The matter came to a head on 4 May 1943, at a meeting in the Royal Army Medical College X-Ray School. In the argument, which covered every aspect of the situation, Colonel Allen granted that no harmful results might accrue to the technicians over a year or two, in spite of secondary radiation from the patient, but he called to the committee's attention the following points:

1. Many technicians might decide to continue in this field in civil life.
2. The question of pensions after the war had to be considered.
3. The compensation situation in the United States differed from that in Great Britain in that all U.S. radiologists were protected for indemnity against legal proceedings instigated by patients.

By holding firmly to this position, Colonel Allen finally won his point and the committee issued a statement that "* * * in view of the special circumstances, the conference agrees that the arrangements for American X-ray technicians must be left to the discretion of the American Consulting Radiologist."

Before this meeting, Colonel Allen, with the assistance of the Construction Section of the Hospital Division, Office of the Chief Surgeon, ETOUSA, had drawn up plans for the protective measures considered essential in hospital construction. In all existing X-ray departments and in those to be constructed in the future, there were to be partitions of brick or hollow building tile filled with earth. When the division of a 24- by 24-foot radiographic room was necessary, a brick wall was advised, rather than a wooden partition. Both brick and tile partitions had undergone extensive testing in U.S. Hospital X-ray departments and had been found to be satisfactorily radiopaque. To be absolutely safe, however, and to emphasize further the need for protection of personnel, the plans for ETOUSA hospitals included the use of barium plaster to coat the walls to a height of 6 feet. The plaster was not mandatory, but was recommended because of its salutary effect on the morale of X-ray personnel. U.S. insistence on these protective measures, which were considerably more far-reaching than the British considered necessary, caused some confusion to the constructing agencies, but all X-ray departments constructed thereafter were protected by the measures described.

In October 1943, after the Senior Consultant in Radiology, ETOUSA, had visited the North African theater (p. 419), the following details were incorporated in the protection policies for forward areas in the European theater:

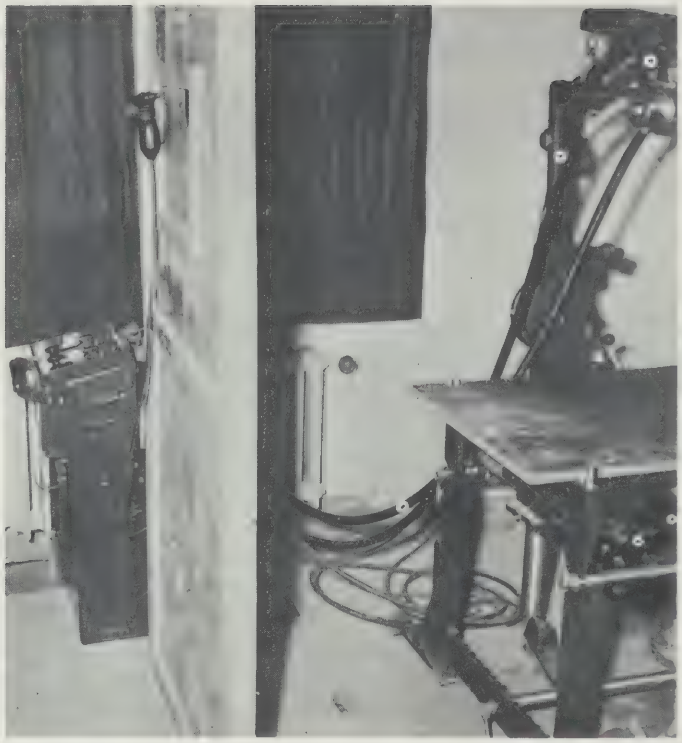

FIGURE 123.—Technique of protection against radiation. Control stand behind improvised lead screen. Because lead glass was not available, a small hole was made through the lead placed in the window frame and the technician looked through it. This was much safer than for him to peer around the edge of the screen.

1. As much metallic lead sheeting as possible was to be made available for screens.

2. When metallic lead sheeting was not available, lead rubber aprons, which were always available, were to be used on improvised wooden frames to form protective screens to be placed between the patient and the technicians. This type of protection also established distance, a valuable precaution which did not exist when technicians wore the aprons. The wearing of lead aprons was not required except during fluoroscopy.

3. A protective arrangement of X-ray departments and improvised protection of X-ray machines was recommended (fig. 123).

Inspection of hospitals.—A number of visits of inspection were made to various installations, with the sole purpose of seeing that the protective regimen outlined had been carried out. In July 1944, the annual report of the

Senior Consultant in Radiology contained the following data and instructions:

1. All X-ray equipment was so constructed as to prevent primary beam exposure. All protection was against secondary radiation from the patient.

2. Every X-ray department in the United Kingdom Base had barium-coated walls protecting the darkroom, the radiologists' room, and the technicians' room.

3. All commanding officers had been advised, when and if radiographic rooms had to be partitioned, to use brick walls down the center, to protect those in one side of the room from X-rays generated in the other side. Several such walls had been installed.

4. Radiographers were ordered to use the protection available. Each one was told to prepare a lead protective screen or lead apron at each table 6-feet distant from the patient. No r meters were available for measuring personal exposure, but film tests were to be made routinely. In some hospitals, routine blood counts were also made.

5. Radiologic consultants were urged to check exposure and protection at their visits to each installation.

Protection in Forward Areas

The 22 installations visited in the forward areas in July 1944 had all made serious efforts at protection, though the Senior Consultant in Radiology noted several times in his official diary that the nearer the front the installation was located, the less satisfactory were protective measures. Their importance was emphasized at all visits, and installations were always inspected from this point of view. The status of protection in forward hospitals was, on the whole, consistent with the limitations necessitated by their mobility and transportation weight requirements.

One of the best and simplest of protective methods consisted of adding distance from the source of radiation by lengthening the cords to which timers were attached. Some radiologists, when 6-lead primary cable was available, separated the whole control stand of the Army Field Unit (No. 96085) from the transformer and placed it behind a wall or protective screen.

On the Continent, the chief difficulty in implementing protective measures was that the original plans for an early change from tents to prefabricated huts did not materialize, and more individual screening was therefore necessary. Whenever an existing building was utilized, there was, of course, a problem of protection peculiar to that special installation. A 6-inch European type brick wall furnished reasonable protection.

Later Protective Techniques

On 31 December 1944, Circular Letter No. 149 was issued outlining the fundamental principles and techniques of protection for patients and X-ray

workers (*6*). At that time, the permissible X-ray dose per radiologist or technician was considered to be 0.3 r per week. There was, however, no apparatus to measure the dose. The use of dental film badges was recommended.

On 18 February 1945, Col. S. B. Hays, MC, Chief, Finance and Supply Division, Office of the Chief Surgeon, ETOUSA, sent a letter to base surgeons advising them that sufficient lead sheeting was now available in their respective sections "to allow a maximum issue of 3 units per hospital."

In July 1945, the protective measures established in 1943 in rear area hospitals were still in effect. Hospital center inspectors, whose comments were often arbitrary and based upon inaccurate or incomplete technical knowledge, were requested to confer with radiologic consultants before making recommendations or decisions concerning X-ray protection in future construction. The request was not generally effective, though an occasional cooperative inspector discussed the situation with a regional consultant or a hospital radiologist. Protection is an important point to bear in mind in radiologic preparations for a future war.

Rotation of Personnel

As the war progressed, another measure for protection of personnel was instituted; namely, their rotation from forward to rear areas. This practice, combined with the protective measures described, was extremely effective.

Of the more than 400 radiologists who served in the European theater, only 1 is known to have suffered from the effects of excessive exposure to X-ray. He was the radiologist of an evacuation hospital that had been active in the North African, Sicilian, and Normandy campaigns. Routine fluoroscopic localization of foreign bodies was the practice in this hospital, and it was not unusual for him to remain in the fluoroscopic tent for several hours daily without relief. Radiologic consultants had been unable to prevail upon the commanding officer and the surgical staff to utilize anteroposterior and lateral radiographs instead of fluoroscopy for foreign body localization in this hospital. In November 1944, after several months of the kind of work described, the radiologist was admitted to a general hospital in the United Kingdom with anemia, and later he had to be returned to the Zone of Interior.

HANDLING OF RADIOGRAPHS

Identification

Upon the advice of the Senior Consultant in Radiology, the Chief Surgeon, ETOUSA, in March 1944, directed that all X-ray films be identified by the patient's name, rank, and serial number, and the date and name of the hospital at which they were made.

Lead letters and lead numbers, used to mark films, were easily and

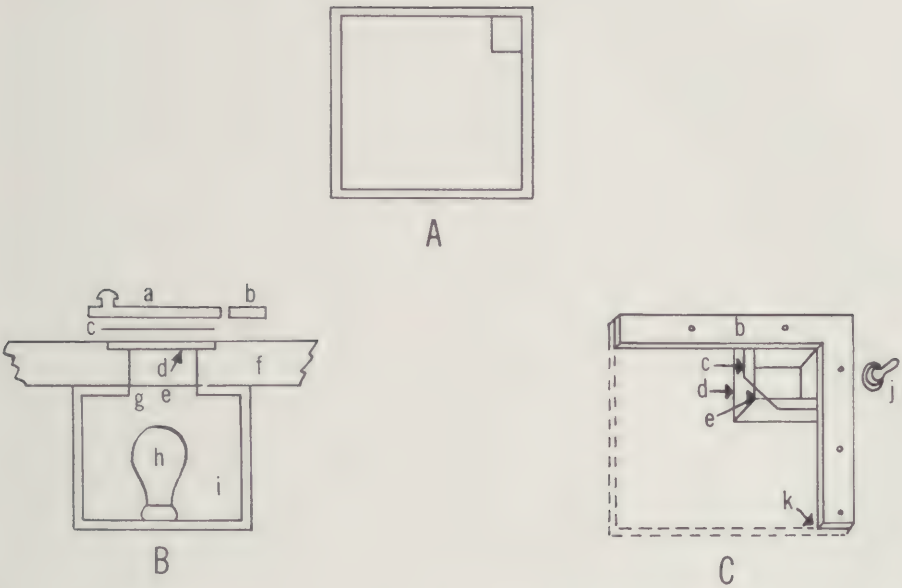

FIGURE 124.—Flash-box technique of identifying radiographs. A. Cassette with lead mask 5 by 6.5 cm., which prevented exposure of this area of film. B. View of flash box from above: Door (a), doorjamb (b), clear film (c), glass (d), aperture in table (e), tabletop (f), filter (g), light (h), light-tight box (i), toggle switch (j), and guide (k). C. Cross section of flash box.

quickly lost, and the problem of keeping an adequate supply was extremely difficult in the European theater. Some radiologists used hand-whittled lead numbers. Some used the soldiers' identification tags. Some met the problem by having their hospital dental departments make lead markers for them, by making molds of plaster of Paris and pouring molten lead into them. Considerable experimentation was required to produce a properly shaped form from which the cold lead numbers could be removed without splitting it.

Other radiologists preferred to use a flash box (fig. 124), which would be readily improvised from materials at hand (*7*). While techniques varied, the following method was more or less typical:

To provide space on the film for the identification data, one corner of each cassette was protected from exposure while the radiograph was being made by a lead sheet (5 by 6.5 cm.) held in position by adhesive strips. The flash box was constructed by making a hole in the protected corner in the darkroom tabletop of the same size as the lead sheet. This hole was then covered by a piece of glass, 7 by 6 cm., countersunk to make it level with the tabletop. Above the glass was a drop-type door, hinged with adhesive tape, and of the same size as the glass. When this door was lowered, the glass was completely covered. A ruby or ordinary light bulb (15 watt) was attached beneath the table in a suitable light-tight box and was activated by

a switch mounted on the tabletop. The bulb was energized by the general lighting system or by flashlight batteries.

The identification information printed on a slip of paper was passed into the darkroom along with the cassette and placed on the glass cover. The cassette was then opened and the unexposed corner of film was fitted accurately over the slip of paper. After the hinged door was closed the light was flashed on, and the information on the paper was thus recorded on the film. The exposure time depended upon the type of bulb used. If reversed carbon paper was used under the identification slip, the shadow of the transmitted data was much blacker.

The flash-box technique was the most satisfactory of all methods of identifying radiographs. A single handling was all that was necessary. The data became a permanent part of the film. The fact that the lead markers were permanently placed on the cassette was a great help in determining the right and left sides of the film when the usual markers had been forgotten or misplaced. The technique was practical in both evacuation hospitals and mobile X-ray units. It was time-saving, and those who used it described it as foolproof. It was so successful, in fact, that its use might well have been made routine.

Transfer of Radiographs With Patients

Radiographs are an integral part of a patient's clinical record. Theoretically therefore they should be handled like all other clinical records, being plainly marked, first of all with the patient's name, rank, and serial number, and the date and hospital at which they were made.

In civilian practice, the handling of roentgenograms does not present much difficulty. In military practice, numerous problems arise because of their variable size, their ready destructibility, their peculiar clinical value, and the frequent movement of patients from hospital to hospital.

In World War II, it was found impossible to depend on regular medical record procedures to assure the maximum usefulness of radiographs. It was equally evident that to handle them in a way that would assure their maximum usefulness and that would permit them to be readily utilized in the speedy triage and evacuation of patients, special procedures and special directions would be necessary. In order to standardize these procedures, it was necessary to issue instructions concerning them from the Office of the Chief Surgeon, Headquarters, ETOUSA.

Development of policies.—The problems involved in the handling of radiographs had several aspects:

The first problem concerned the large numbers of films which had accumulated in each X-ray department because the patients on whom they had been made had died or had been returned to duty from the particular hospital. In view of the possible postwar value of these radiographs in adjudicating disability claims, a letter was addressed to The Surgeon General on 23 January 1944, requesting instructions for their handling and disposal.

A direct reply from Lt. Col. (later Col.) Byrl R. Kirklin, MC, Consultant in Radiology, Office of The Surgeon General, directed that all accumulations of films be disposed of at the end of 90 days except those of historic and scientific interest. Hospitals and dispensaries in the European theater were given these instructions, which proved most useful in clearing X-ray departmental files in preparation for D-day.

The second problem concerned the handling of radiograms of patients still in hospitals or destined for transfer to other hospitals.

Before D-day, hospitals were encouraged to keep all such roentgenograms filed in the X-ray department, where they would be readily accessible to all who needed them. The policy was not popular with some orthopedic and other surgeons, who preferred that radiographs be kept on the wards. Central filing was the logical procedure, however, as long as the number of patients was limited and the date of their discharge or evacuation could be predicted.

After D-day the situation was very different. It soon became evident that in fixed hospitals in which large numbers of casualties were being received and evacuated, the most efficient plan was to keep the roentgenograms with which the X-ray department had finished, on the ward with the patients. Here they would be ready for immediate use by the ward surgeon and the consultants, and even more important they would be available for transfer with the patients.

This reversal of policy caused a certain amount of confusion, as well as considerable criticism of the Senior Consultant in Radiology, because he had first directed that radiographs be kept filed in X-ray departments and then had directed that they be kept by the patients' beds. The changed policy, of course, was simply another instance of the flexibility required to meet the changing conditions of war. Adaptability to circumstances was quite as necessary a quality in the medical officer as in other military personnel.

The filing of X-rays on wards placed three responsibilities upon the chief of service or the ward officer: The X-rays had to be preserved against loss or damage. They had to be returned temporarily to the X-ray department when the patient required further roentgenologic study. Finally, they had to be transferred with the patient. The usefulness of radiographs on the ward was increased by the requirement that a copy of the radiologist's report, other than the copy in the field medical record, be attached to all envelopes containing radiographs, so that the report would always be immediately available to medical officers when they made their rounds.

Colonel Allen had always believed that roentgenograms should accompany individual patients as they progressed from the frontline to the Zone of Interior. How to accomplish this he took under serious consideration after a visit he made to the British and U.S. sectors in North Africa in September 1943 (p. 419). Even after a long military experience, the British Consultant in Radiology in that area, Lt. Col. John King, RAMC, was still undecided as to what plan was best to convey radiographs from the front to the rear

areas, so that they would be most useful in treatment of the patient in successive hospitals. All methods that he had tried had serious drawbacks.

Colonel Allen finally decided that the importance of having radiographs accompany individual patients was so great that, if necessary, they should be tied to casualties who could not care for themselves.[6] To this end, a campaign of instruction was inaugurated in January 1944. It included administrative memorandums, letters, directives, an article in the *ETOUSA Medical News Bulletin*, and, probably most important, frequent inspections.

Only continuous application to the problem throughout the fighting on the Continent kept patients and their radiographs together. The Senior Consultant in Radiology, ETOUSA, regarded this objective as among his most important duties because of the advantages inherent in the plan for both patients and hospitals.

The regulation that radiographs should move with the patient was based on the practical consideration that the films were useful from the moment they were made until his treatment was concluded in the Zone of Interior. All of them were helpful, but those made in forward areas were, on the whole, more valuable than any others. They not only supplied valuable diagnostic information, they also furnished officers assigned to triage in services of supply hospitals with accurate information useful in sorting patients, especially when large convoys were received. The films also presented graphically to surgeons in rear hospitals the conditions that had confronted surgeons in the forward hospitals in which the casualties were first received. The radiographs that traveled with the patients thus fostered a continuing policy of medical care and also engendered a better comprehension of the treatment that had been instituted in forward hospitals. Finally, movement of the radiographs with the patients saved repeated and unnecessary examinations, thus sparing them discomfort, conserving scarce materials, reducing costs, and also reducing the need for litter bearers, who, as noted elsewhere, were always in short supply.

At first, the campaign to have radiographs accompany patients was not more than 65 to 75 percent successful. Oddly, the best results were achieved in forward hospitals. As the war progressed the policy became more and more effective, though it always presented difficulties because of the varying status of the patients; their definitive disposal and segregation; the different types of transportation (ambulance, rail, water, and air); and the frequent changes in medical personnel.

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1. Annual Report, Senior Consultant in Radiology, ETOUSA, 1943.
2. Annual Report, Senior Consultant in Radiology, ETOUSA, 1944.

[6] Thousands of radiographs were tied to casualties who could not take care of the films or themselves en route. Films were tied to casts, to the buttonholes of blouses or trousers, to shoelaces, and to epaulets or buttons on the shoulder of the uniform. Some films were tied around the legs and others around the arms. Once patients able to care for themselves understood the point of sending their radiographs along with them, they usually volunteered to handle their films themselves. Many of them used the methods just described for helpless casualties.

3. Annual Report, Senior Consultant in Radiology, ETOUSA, 1945.

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CHAPTER XI

Personnel and Training

Kenneth D. A. Allen, M.D.

OFFICER PERSONNEL

1943

During 1943, the general and station hospitals arriving in the United Kingdom, as well as those already there when Col. Kenneth D. A. Allen, MC, Senior Consultant in Radiology, ETOUSA (European Theater of Operations, U.S. Army), assumed his responsibilities, were adequately staffed with radiologists, at least from a strictly academic point of view. During 1943, the principal personnel problems faced by the consultant, and later by the regional consultants, were as follows:

1. The appraisal of the radiologists already in the United Kingdom and those who arrived during the year, to determine their proper classification and assignment in relation to their abilities (so-called vetting).
2. The orientation of these radiologists in military and oversea service.
3. Their instruction in the administration of Army hospital X-ray departments.
4. The military and technical training of X-ray technicians (p. 361).

These responsibilities were carried out at first chiefly by personal visits to hospitals by the senior consultant and by meetings and conferences. After the fall of 1943, he was materially assisted in these efforts by the newly appointed regional consultants (p. 328).

1944–45

On 14 January 1944, a letter from the Office of The Surgeon General completely changed the personnel picture. It stated that present indications were that general hospitals sent to the theater after March 1944 would have "practically no specialists." Estimates suggested that 103 hospitals would be affected.

The Senior Consultant in Radiology, ETOUSA, proposed, as a solution of this problem, that an immediate training program be instituted in the theater to give nonradiologic medical officers sufficient training to permit them to serve full time in each general hospital which was without a chief of the radiologic service. It was believed that the first 90 hospitals sent to

the United Kingdom without radiologists could be provided for in this manner. Colonel Allen further suggested that the Chief Surgeon, ETOUSA, cable a request to the Office of The Surgeon General that all general hospitals above this number be staffed with a radiologist capable of heading the department.

In connection with the first of these suggestions, the Chief Surgeon, ETOUSA, issued Administrative Memorandum No. 49, on 21 April 1944 (*1*), directing the commanding officer of each general or 750-bed station hospital in the United Kingdom to select an appropriate medical officer for full-time duty and training in an X-ray department. Preferably, the officer selected would have some experience in radiology or some interest in it. As a result of this training program, it was thought that the radiologic service in the theater in 1944, in spite of the added load after the invasion of the Continent, could be maintained on the same high level as the service in 1943.

The general policy was to secure department heads for those general hospitals that were without radiologists in two ways:

1. By transferring to them experienced radiologists in station hospitals who had been in the theater for the longest time.

2. By transferring to them capable assistant radiologists in affiliated hospitals.

The policies just described were also used to compensate for the attrition that had begun to be a factor in radiologic personnel. By November 1944, the theater had lost eight of its best radiologists, some of them chiefs of services, because of such conditions as cardiac disease, hypertension, epilepsy, anemia (p. 338), and peptic ulcer. All but two of the eight had been in the theater for 18 months or longer.

Other problems confronting the radiologic consultants had to do with the qualifications of radiologists who had arrived in the theater. By the end of 1944, 35 general hospitals had arrived with chiefs of service who were not qualified for their assignments. Other hospitals had departmental heads who needed considerable support from the Senior Consultant in Radiology, ETOUSA, and the regional consultants. Finally, five hospitals had chiefs of radiology who were able to retain their assignments only by virtue of the capabilities of their assistants.

Professional Classification

MOS classification.—On 1 December 1944, the qualifications of all radiologic officers in general and station hospitals who had been in the theater long enough for classification were appraised according to the Adjutant General's Qualification and Appraisal Rating, which prescribed the basis for determining the proficiency rating of officers.

This appraisal resulted in the following distribution of ratings:

A (professorial qualifications), 4, all in general hospitals.

B (certified by the American Board of Radiology), 43, 41 in general and 2 in station hospitals.

C (eligible for Board certification), 99, 76 in general and 23 in station hospitals.

D (completed at least 1 year residency training), 74, 57 in general hospitals and 17 in station hospitals.

Other radiologic officers in general hospitals, including some assistants and other personnel trained under the provisions of Administrative Memorandum No. 49, were all classified as "partly trained" and were rated below D. A list of these below-D officers was constantly kept current, for presentation to the Training Section, Troop Movements and Training Branch, Operations Division, Office of the Chief Surgeon, ETOUSA, whenever opportunities for training arose. It was later submitted to the Redeployment Branch, Personnel Division, Office of the Chief Surgeon, ETOUSA, with suggestions as to how officers with such a limited amount of training could be used.

Generally speaking, the Senior Consultant in Radiology, ETOUSA, apparently classified radiologists by lower professional ratings than did his counterparts in other theaters. He did, however, certify all radiologists with MOS ratings of C to the theater chief surgeon as capable of serving as chiefs of the X-ray section in any general hospital. Most class B radiologists were also qualified to serve as such; the latter group therefore were placed on the list of eligibles from which consultants were selected whenever replacements were necessary because of attrition or redeployment.

It shortly became obvious that radiologists in evacuation hospitals should have an MOS rating, and a corresponding proficiency rating, of at least D 3306. Before these ratings became official policy, there were too many occasions on which it was necessary for experienced surgeons in these hospitals to point out to inexperienced radiologists instances in which the interpretation of films had been incorrect or in which the condition under investigation had not been depicted clearly because of faulty radiography.

In the spring of 1944, because of the proposed differentiation and specialization of medical services to be rendered by general and station hospitals after the invasion, it became necessary to classify radiologists in the theater not only according to their MOS ratings but also according to their specialized radiologic abilities. The classification and reassignment of radiologists so that their specialized abilities would parallel the proposed segregation of casualties, though held to the lowest practical minimum, continued after D-day and to the termination of hostilities. These duties occupied a great deal of the time and attention of the Senior Consultant in Radiology, ETOUSA, who had the assistance, at all times, of at least one of the regional consultants. The number of qualified radiologists was limited, and those available had to be so distributed as to maintain the same professional level as that of other specialists in any given hospital. This required careful appraisal of each of them, as well as frequent consultations with senior consultants in other specialties.

Until 6 June 1944, the radiologic specialists destined for forward assignments did very little radiology, but all of them were thoroughly oriented and prepared for their duties on the far shore.

In June and July 1944, when casualties began to be received in large numbers in the United Kingdom from the Continent, unpredicted and unexpected changes in evacuation policies by the Evacuation Branch, Operations Division, Office of the Chief Surgeon, ETOUSA, brought about changes in the duties of specific hospitals and greatly increased the difficulties of providing specialized radiologic care in ophthalmology, neurosurgery, and other specialties. Better coordination between all divisions of the Chief Surgeon's Office finally ended these difficulties.

Changes of Assignment

By the end of 1944, the Senior Consultant in Radiology, ETOUSA, had found it necessary to make 70 major transfers of radiologic personnel. These transfers were necessary:

1. To maintain a proper level of professional care in hospitals in the communications zone.

2. To furnish forward areas with badly needed radiologic officers.

3. To allot officers specially qualified in certain aspects of radiology to hospitals designated to receive casualties who required specialized care, such as neurosurgical and ophthalmologic casualties (p. 347).

These 70 transfers were divided as follows:

19 assistant radiologists transferred from general hospitals to serve in station hospitals.

14 assistant radiologists transferred from general hospitals to serve as chiefs of service in other general hospitals.

21 radiologists transferred from station hospitals to serve as chiefs in general hospitals.

16 chiefs of service or assistant radiologists in station and general hospitals to serve in evacuation hospitals and auxiliary mobile X-ray units.

Each change, it should be emphasized, required another change to compensate for it, and still other shifts were necessary as a result of having to send radiologic officers to forward hospitals without replacements in kind for them.

Rear hospitals became a source of selection and exchange of radiologic officers needed to staff the X-ray departments of forward hospitals. The transfers were difficult to accomplish. Continuous persuasion was required to prevail upon the Personnel Division, Office of the Chief Surgeon, ETOUSA, to make radiologic officers in rear areas available for hospitals in the Army Zone. Resistance to such changes of assignment was particularly notable in the March-June 1944 period. Originally, also, there was considerable competition between rear and forward hospitals in securing radiologists for their units, although it eventually subsided as the realization

grew that rear areas should supply forward units with personnel rather than compete with them for personnel.

Utilization of Radiologists

Use of radiologists for nonradiologic assignments.—It was the established, and generally followed, policy of the Personnel Division, Office of the Chief Surgeon, ETOUSA, to assign specialists according to their MOS rating. In several instances, however, during the late spring of 1945, commanding officers of hospitals assigned officers with an MOS 3306 (radiologist) rating to positions that could have been filled by officers with a classification of MOS 3100 (medical officer, general duty). For example, one general hospital, for a period of many months, had three radiologists, two of whom spent the major portion of their time in nonradiologic duties. Efforts to move at least one of them to an evacuation hospital in which a radiologic officer was badly needed were resisted by the commanding officer. Not until weeks later, when their redeployment orders were received, was it possible to get these two officers back into radiologic assignments in other hospitals. The radiologist with a B rating, who had carried most of the X-ray work for the evacuation hospital just mentioned, was so exhausted when the time for his redeployment came that, though he had a low score, he could not be directly redeployed.

Radiologists in general hospitals.—It was Colonel Allen's observation that a general hospital in the European theater with a daily average of 600 or more patients needed two full-time radiologists because of the nature of the workload, the necessity for training technicians, and the importance of occasional escape from the detrimental effect of X-rays. In spite of the shortage of medical officers and the tendency of certain commanding officers to allot key specialists to nonspecialist assignments within the hospital or to resist demands for lending them on detached service, statistics derived from 291 quarterly reports from 125 general hospitals showed that commanding officers kept an average of 1.8 radiologists in their X-ray sections at all times. This policy was in striking contrast to the practice of the occasional commanding officers who insisted that a single radiologist do all the departmental work.

Radiologists in evacuation hospitals.—After the invasion of the Continent, there was a continuing need for additional personnel to supply the insistent calls for radiologic service from forward hospitals and surgical teams. Observation of forward hospital X-ray departments during heavy engagements in Normandy convinced the Senior Consultant in Radiology that not more than half enough radiologists and X-ray technicians had been authorized for them. When these hospitals began to function, their X-ray departments usually had to be operational for 24 hours a day, and a single officer could not possibly handle such a load. Another reason for the assignment of a second officer was that technicians could not be left without super-

vision for 12-hour periods when battle casualties were being received. At the end of the war, it was firmly established that at least two radiologic officers were necessary in 400-bed evacuation hospitals, as well as in 750-bed hospitals, because of the greater turnover of patients in the smaller hospital. One of the radiologists should be an experienced officer, with a rating of C or D, and the other an assistant with at least 4½ months' training in an Army radiology school in the Zone of Interior (p. 30), or with equivalent civilian training. Even when three mobile auxiliary X-ray units were on call to augment hospital X-ray departments, each 400-bed evacuation hospital still needed two radiologic officers.

Many commanding officers, realizing the need themselves, arbitrarily assigned two full-time radiologists to their X-ray departments. Quarterly reports from 12 evacuation hospitals, for instance, showed an average of 1.7 radiologic officers in these hospitals, in spite of the shortages of radiologic officers and the lack of provision for a second officer in their tables of organization.

Radiologists in field hospitals.—Assignments of radiologic personnel to field hospitals were made chiefly by commanding officers who selected, arbitrarily, the man in each unit who seemed best qualified to perform these duties. The situation was difficult. The supply of qualified radiologists in the theater was not large enough to permit radiologic coverage of each of the three platoons; they were too widely separated and their work was too diversified.

On the average, from 10 to 20 radiographic examinations were required in a field hospital during each 24-hour period. In these cases, all that was usually necessary was routine anteroposterior, and sometimes lateral, radiographs of the thick portions of the body, to furnish the surgeon with a gross guide to his procedure. The films were usually made without moving the patient from the litter on which he was brought into the hospital.

Difficult radiologic problems sometimes confronted medical officers in field hospitals, but they were not numerous, since these organizations received only nontransportable casualties. Occasionally, the X-ray department of a field hospital was also called upon for a certain amount of outpatient care from neighboring combat units.

Although attempts were made to furnish field hospitals with the most capable possible technicians, this plan did not solve the personnel problem, for a technician generally became less efficient without a radiologic officer to supervise his work. The best plan, on the whole, was to provide a field hospital with at least one surgeon who had some knowledge of radiography. A surgeon who had completed a course at one of the schools of radiology in the United States was an ideal assignment for the staff of a field hospital.

It had been expected that a radiologist from an auxiliary mobile X-ray team would occasionally be sent to a field hospital unit from Army headquarters, but only a single such instance came to the attention of the Senior

Consultant in Radiology, ETOUSA: On the near shore, just after D-day, an X-ray team furnished invaluable service to the beach platoon of the 50th Field Hospital, which received casualties from cross-Channel boats coming back from Normandy.

Military Rank and Administrative Status

On 29 September 1944, the Chief Surgeon, ETOUSA, invited recommendations for promotions, and, on 7 October, the Senior Consultant in Radiology, ETOUSA, recommended the promotion of 23 majors to lieutenant colonel, of 37 captains to major, and of 24 first lieutenants to captain. The basis of his recommendations was that the current ranks of the officers in question were generally lower than their qualifications warranted and were also lower than tables of organization permitted. The promotions which resulted had an excellent effect on morale.

As of 1 January 1945, the X-ray departments of 126 general and 43 station hospitals were staffed by 15 lieutenant colonels, 70 majors, 120 captains, and 46 first lieutenants. This was a total of 251 radiologic officers.

The Senior Consultant in Radiology, ETOUSA, and his regional consultants were occasionally confronted with difficulties arising from the fact that the radiologist, especially in station hospitals, was administratively assigned under either the medical or the surgical chief of section. Some confusion and inefficiency resulted from this chain of command. There were no such difficulties in hospitals in which the radiologist served directly under the commanding officer or under the chief of professional services. The senior consultant had early come to the conclusion that, since the department of radiology served all the special sections in the hospital as well as the medical and surgical services, the radiologist should appropriately be rated as a chief of service and should be directly responsible to the commanding officer or the chief of professional services.

The confusion could easily be understood. In Technical Manual 8–260 (*2*) it was recommended that the radiology service be directly under the commanding officer in general hospitals, and most, though not all, commanding officers followed this policy. The situation in station hospitals was confused by the fact that the manual indicated in one place that the radiologist should be assigned to the surgical service and in another that he should serve directly under the commanding officer. Nothing was said about his administrative status in evacuation or field hospitals.

Most of the difficulties concerning hospital status were encountered before April 1944. There were few hospitals in which, when the matter was brought to their attention, the commanding officers did not cheerfully concur in the policy of giving radiologists equal status with the chiefs of medicine and surgery.

Rotation

On 30 November 1944, the Senior Consultant in Radiology, ETOUSA, recommended in letters to Army surgeons, through channels, that radiologists in certain forward areas and in auxiliary mobile X-ray units should be rotated for 60 days with selected radiologists in station and general hospitals. Rotation had several advantages. It enabled both groups to become acquainted with each other's problems. It provided much needed rest for hard-pressed forward personnel. It removed them from assignments of considerable X-ray exposure. Finally, it aided in a more universal adherence to the policy that their radiographs should accompany all patients from forward hospitals to the Zone of Interior (p. 340).

A similar policy of rotation was later approved by General Hawley for all medical officers.

By the latter part of 1944, there were 25 or more radiologists who needed to be rotated because of exhaustion; some of them required permanent assignment to the Zone of Interior. The attrition rate (p. 346) was rising, but by the policy of rotation many could be salvaged for service in the theater. At least 12 of the recommended rotations are known to have been accomplished.

Redeployment

The problems involved in redeployment in the summer of 1945 caused a great deal of concern, for several reasons, to all the consultants in the Professional Services Division, Office of the Chief Surgeon, ETOUSA. These problems were:

1. Specialists with adjusted service rating scores or points that were low within their particular base section but that were not low for the theater as a whole were alerted for direct redeployment to the Pacific areas, regardless of their physical status.

2. The professional balance of hospitals to be redeployed was not taken into consideration by the officers in charge of redeployment.

3. As a result of the policies employed, some hospitals remaining in the theater did not have sufficient personnel to care for the remaining caseload and the new patients likely to be received.

To remedy these problems, the Senior Consultant in Radiology made the following recommendations to the Chief Surgeon, ETOUSA:

1. That all radiologists of the theater be scored centrally by comparative service scores for redeployment to the Pacific, to obviate the possibility of inequities due to varying assignments within the theater where "points" were computed differently.

2. That all assignments for direct radiologic redeployment be scrutinized by the Senior Consultant in Radiology who knew of certain men regardless of score who were too war-weary (and yet without physical profile D) to hold up in another foreign theater, but who would render good service in the ZI, which was short of radiologists. A list of such officers was given to the redeployment section.

3. That every precaution be taken to insure that the thousands of patients still in

ETO hospitals, and the hundreds being admitted, continue to be served by expert radiologic care.

4. That hospitals be permitted to treat patients until within thirty days of the time the hospital was scheduled to move and thus shorten the many weeks in staging areas.

Even if all of these suggestions had been fully implemented, general hospitals destined for the Pacific would have lacked the balance and the high level of professional qualifications achieved in the European theater by the careful appraisal and assignment of personnel by the consultants in the Professional Services Division, Office of the Chief Surgeon, ETOUSA. The officer sent to the European theater as Chief of Redeployment, a pharmacist by training, made arbitrary decisions on matters in which he was not qualified to judge, generally refused to accept advice from those professionally qualified to advise him in these matters, on occasion disregarded telephone orders and other orders from his superiors, and created a great deal of confusion and bitter feeling. As a result, too little attention was paid to professional qualifications and hospital needs in redeployment, and many hospitals were ordered to the Pacific staffed with war-weary medical officers, many of them radiologists, whose physical condition and length of service entitled them to return to, and assignment in, the Zone of Interior.

TRAINING OF OFFICER PERSONNEL

Orientation

Because many of the radiologists in the theater were young and inexperienced, it was necessary to provide refresher courses for them in their specialty, as well as to provide for their orientation not only in military service but in military service overseas.

As part of the orientation of newly arrived radiologists, the Senior Consultant in Radiology, ETOUSA, or a regional consultant visited them in their departments, to instruct them in the details of oversea service, in military roentgenology, and in the use of foreign-made equipment (p. 370). The radiologists were also required to attend group meetings, where they listened to talks and engaged in discussions. Beginning in the fall of 1944, meetings to discuss current problems were held more often. These meetings were generally held in base sections and were presided over by regional consultants when Colonel Allen could not be present (p. 355).

Training in British Hospitals

By personal arrangements between the Senior Consultant in Radiology, ETOUSA, and Dr. A. E. Barclay, Consultant in Radiology to the British Ministry of Health, plans were consummated to permit selected U.S. radiologists to receive training in six or seven outstanding British radiologic centers. These courses lasted for 21 days each.

Refresher courses consisting of 48-hour observation tours under the personal tutelage of Brigadier D. B. McGrigor, RAMC, Chief Consultant in Radiology to the British Army, and Lt. Col. R. Boulton Myles, RAMC, Commanding Officer of the Royal Army Medical College X-Ray School, were carried out at that school from December 1944 until September 1945. The officers to attend these courses, which were highly instructive and extremely popular, were designated by the respective base surgeons, who were requested to bear in mind in their selections the importance of cordial liaison with the British. The selection of students was excellent and these courses aided markedly in cementing the already fine relationship between British and U.S. radiologists (p. 330). Two other officers were assigned for 30 days each to temporary duty in the X-ray department of the British Schenley General Hospital.

The correspondence, directives, and reports of arrangements for these courses appear in detail in the final report of the Senior Consultant in Radiology, ETOUSA (p. 325).

Arrangements were underway for providing training, of the kind just described, in Belgium and France during the summer of 1945 but were discontinued when the war in Europe ended on 8 May.[1] Training opportunities were sought in Sweden by Capt. Martha E. Howe, MC, who visited several radiologic centers in that country as a deputy of the Senior Consultant in Radiology. She found no opportunities for training because the Swedish radiologists, overmodestly, believed that, having been out of touch with world radiology for some time, they were not competent to offer any instruction of value.

Training in U.S. Hospitals

During 1943 and the spring of 1944, resident training was offered to selected officers who had had at least 1 year of radiologic experience by transferring them to U.S. general hospitals for 30 days of instruction under outstanding radiologists.

It was found that the best assignment for radiologic students with less experience (those who had completed the 6-weeks' intensive course at a radiologic school or who had had 4½ months of Army training) to begin their active war service was either in general hospitals, as assistant radiologists, or in field hospitals. It was preferable that those assigned to field hospitals be qualified also in medicine or surgery. There was not sufficient radiologic work in a field hospital to occupy a radiologist full time (p. 350).

All resident training was suspended just before V–E Day except for radiologists taking part in the 60-day rotation program.

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[1] As a matter of fact, it would have been relatively simple, and highly profitable, to assign officers to take these courses, but the officer in charge of redeployment could not be convinced of the professional wisdom of such assignments and the extraordinary opportunities thus offered and unlikely to be repeated.

Plans for Postwar Training

In the spring of 1945, extensive plans were made for a continuation of the resident training program in U.S. hospitals after the cessation of hostilities in the theater. A complete list of prospects for radiologic training was forwarded to the Training Section, Operations Division, Office of the Chief Surgeon, ETOUSA, with the officers on it classified professionally into MOS categories. Colonel Allen advised that no officer with less than a year's experience in radiology be considered eligible for this type of training if it entailed moving him from his station. He also advised that class C and class D radiologists from forward areas be sent to U.S. Army general hospitals in which radiologists classified as A and B were on duty. Because of the confusion of redeployment, few transfers had been effected under this program by 1 August 1945.

Professional Meetings

Theaterwide meetings.—It had been the hope of the Senior Consultant in Radiology, ETOUSA, that he could hold a general radiologic meeting at least once every 6 months before D-day, to be attended by all radiologists in the United Kingdom Base. Because of transportation difficulties, however, and the difficulty of billeting the officers in London, only two such meetings could be convened.

The first meeting of the entire radiologic officer personnel in the theater was held on 22 May 1943, at the British Institute of Radiology, 32 Welbeck Street, London, in the area to which medical men had moved when Harley Street was bombed. Twenty-two radiologists were present.

Brigadier D. B. McGrigor, RAMC, Consultant in Radiology to the British Army, discussed the standardization of X-ray equipment in wartime. His talk was of great assistance to the U.S. Senior Consultant in Radiology in solving the difficult problem of reconciling U.S. radiologists and technicians, many of whom had been highly resistant, to the use of British X-ray equipment (p. 370).

The second of these meetings, for which orders were issued for all radiologists "who could be spared," was held on 7 December 1943 and was attended by 56 radiologists (fig. 125). The chief of the Supply Division, Office of the Chief Surgeon, ETOUSA, Col. Walter L. Perry, MC, and two members of his staff discussed the general problems of X-ray equipment, especially procurement and distribution.

At both of these meetings, both military and professional problems in the theater as a whole were discussed by Brigadier McGrigor, Colonel Allen, and others. Both meetings were of great value in the training program.

Other meetings.—Beginning in 1944, the various base sections and hospital centers conducted all-day conferences for the radiologists of the hospi-

FIGURE 125.—U.S. Army radiologists at the 7 December 1943 meeting at the British Institute of Radiology, London. First row: Maj. B. Ehrenpreis, Lt. Col. R. P. Ball, Maj. B. Solomon, Col. W. L. Perry, Maj. D. L. Jellinger, Brigadier D. B. McGrigor, Capt. C. E. Brochu, Lt. Col. K. D. A. Allen, Capt. F. Somma, Lt. Col. J. Spencer, Capt. J. F. Maurer, Capt. A. Bauer, Lt. Col. E. Gray, Lt. A. M. Cherner, Lt. Col. M. I. Smedal, Capt. L. M. Shulman. Second row: Maj. F. Cawley, Capt. A. M. Cove, Capt. R. J. Lutz, Maj. F. Huber, Capt. S. Silvera, Maj. C. F. Ingersoll, Maj. R. E. Avery, Capt. G. D. Davial, Capt. T. B. Bolitho, Maj. J. Hall, Capt. C. D. Bancourt, Capt. L. J. Spitz, Maj. S. Albert. Third row: Lt. J. Jabo, W. O. Dreyfuss, Capt. L. A. Eigen, Maj. A. C. LeDoux, Capt. J. Henderson, Lt. Col. G. W. Murphy, Lt. M. B. Whitman, Capt. H. McCuistion, Capt. B. L. Stein, Maj. D. Joslin, Lt. B. D. Jay, Lt. G. E. Lull, Capt. A. H. Joistad, Jr., Capt. G. Silverton, Capt. O. D. Sabler, Maj. C. P. Naidorf, Lt. Col. M. N. Lancaster, Capt. F. J. Fagan, Capt. S. Dann, Maj. E. Santangelo, Capt. H. B. Nevans, Capt. H. G. Ford, Capt. J. F. Bowser, Capt. J. E. McConchie. Fourth row: Maj. J. D. Southworth, Maj. L. N. Vaughan, Capt. J. P. Palmer, Maj. M. M. Haskell, Capt. K. Cooper.

tals within their jurisdiction, for the purpose of orientation and training and for the discussion of general and current problems, as follows:

9 May 1944	Salisbury, England. At this meeting, the 5th General Hospital, to celebrate the end of its first year in the European theater, presented excellent and instructive medical exhibits and demonstrations, including X-ray exhibits (fig. 126).
6 June 1944	96th General Hospital, Malvern, Worcester, England (during this meeting word came that the invasion had begun).
15 November 1944	53d General Hospital, Malvern, Worcester, England.
2 February 1945	Cherbourg, Normandy, France.
20 March 1945	Reims, France.
26 March 1945	Liége, Belgium.

The experience being acquired by radiologists in the field was reflected in the subjects discussed at the meetings held after D-day as compared with those before it, when the agenda was concerned primarily with the plans and policies for the invasion. After D-day the discussions concerned such matters as evaluation of evacuability and transportability of patients in terms of X-ray evidence; the function of the X-ray department of a hospital in relation to triage; the morale and rotation of X-ray personnel; the handling of radiographs of evacuated casualties and such diagnostic problems as foreign bodies in the thorax near the cardia; the morbidity of sarcoidosis, a number of cases of which had been observed, especially in Negro troops; and the possibility of increased morbidity of tuberculosis among U.S. soldiers.

Intrahospital conferences between the various services proved of great value. They were particularly useful in the early stages of hospital organization, when they fostered mutual understanding and teamwork. Because of the efficiency and confidence that resulted from frequent communication between the chief of the X-ray service and the chiefs of other services, efforts were made to avoid the transfer of hospital radiologists any oftener than was necessary.

Training Material

Texts on radiology for radiologists and on radiography for technicians were an essential part of training but were difficult to procure. It was also difficult to get proper distribution of those which did arrive from the United States, and requisitions for books which were not on hand were simply not filled.

Manuals and texts.—Available Army manuals and Sante's "Manual of Roentgenological Technique" (*3*) were distributed to all radiologists in rear area U.S. hospitals. In May 1945, TM 8–280, "Military Roentgenology" (*4*), was received for distribution from the United States. It is unfortunate that it did not arrive earlier, for it proved an especially useful guide to technique. In the meantime, in order to standardize X-ray technique in forward hospitals, the Senior Consultant in Radiology had prepared a manual on X-ray positioning.

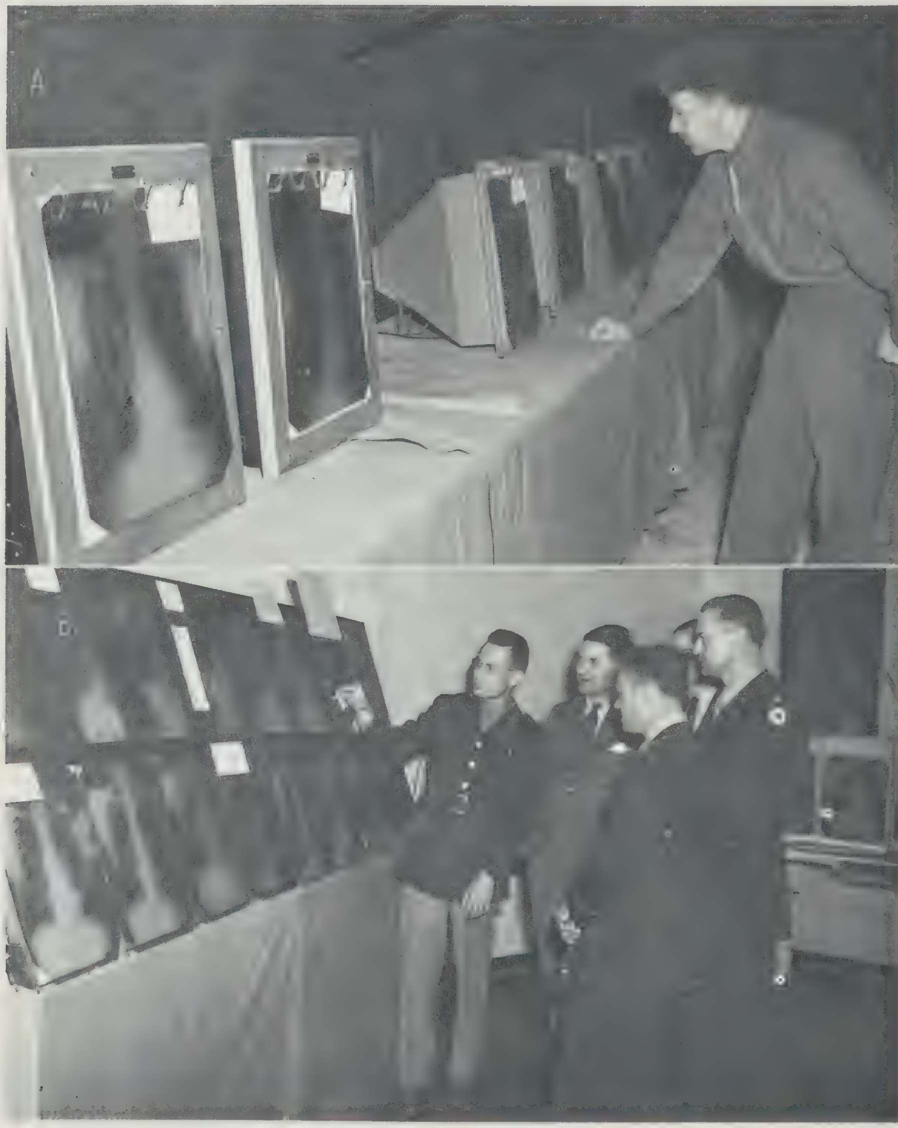

FIGURE 126.—X-ray exhibits celebrating first anniversary of arrival of 5th General Hospital in European theater, Salisbury, Wiltshire, England, May 1943. A. Lt. Col. Theodore L. Badger, MC, Senior Consultant in Tuberculosis, ETOUSA, studying chest X-rays. B. Maj. Jack D. Meyers, MC, demonstrating radiographs to visiting medical officers and British physicians. Lt. Col. Magnus I. Smedal, MC, Chief of Radiology at the hospital, is at the extreme right of the group.

Among the texts purchased for U.S. hospitals from the British were "A Text Book of X-Ray Diagnosis," by Shanks, Kerley, and Twining (*5*); "The Radiology of Bones and Joints," by Brailsford (*6*); and "Positioning in Radiography," by Clark (*7*). Because these orders practically depleted the British supply, the U.S. Army shared its purchases with the British Army at the request of Brigadier McGrigor, the British Army Consultant in Radiology.

Professional journals were also poorly distributed. Copies of *Radiology* and of the *American Journal of Roentgenology and Radium Therapy* would have been most valuable in all station and general hospitals, but they were seldom received. Units in the field could also have made good use of these journals, but they moved so often that it did not seem feasible to attempt to supply them.

X-RAY TECHNICIANS

Assignments

A survey of 71 general and 40 station hospitals operating in the theater during the summer of 1944 disclosed the following grades and distribution of X-ray technicians:

In the 71 general hospitals, there were 59 Technicians, Third Grade; 217 Technicians, Fourth Grade; 285 Technicians, Fifth Grade; and 187 Privates and Privates First Class. This was a total of 748 enlisted men, representing an average of 10.5 technicians per hospital.

In the 40 station hospitals, there were 29 Technicians, Third Grade; 63 Technicians, Fourth Grade; 108 Technicians, Fifth Grade; and 63 Privates and Privates First Class. This was a total of 263 enlisted men and represented an average of 6.6 technicians per hospital.

The total number of enlisted personnel in the general and station hospitals, 1,011, represented less than half of the technical X-ray personnel who served in the theater from the beginning to the end of the war.

At the time that this survey was made, there was an average of 6.2 technicians in four (sampled) evacuation hospitals and an average of 4.7 in three (sampled) field hospitals.

It was the opinion of the Senior Consultant in Radiology, ETOUSA, after his tour of forward area hospitals in Normandy, that the tables of organization for 400-bed evacuation hospitals should be increased by 100 percent for X-ray technicians. Many commanding officers, cognizant of the work these men were doing, arbitrarily increased the number assigned to the X-ray department. The four enlisted men officially allotted could hardly carry the department for 12 hours and could not possibly carry it during the 24-hour periods required when the hospitals were receiving casualties. Even when technicians from mobile X-ray units were available to relieve the hos-

pital technicians, a department with fewer than eight enlisted men could scarcely avoid becoming a bottleneck and delaying initial wound surgery.

When the front was active, after the first 24 to 36 hours, field hospitals which had only one technician, who had been steadily engaged since the push began, often found themselves hampered. Some commanding officers, who realized the specialized nature of X-ray work and the 24-hour service required in periods of stress, arbitrarily arranged for a second technician, selected from their organic personnel. In the European theater, X-ray technicians for field hospitals could be obtained by selecting a trained technician from the X-ray staff of a general hospital, which was provided with a numerical replacement who could be trained.

Technicians in field hospitals had less radiologic supervision than in any other installations. *It was therefore important that they be of the highest caliber.*

On the whole, the X-ray technicians in the European theater rendered superior service, not only in forward areas, where, as at the 35th Evacuation Hospital (p. 443), they often had serious difficulties to overcome, but also in station and general hospitals.

Grades

A comparison of the grades of enlisted technicians in the X-ray department with those of technicians in dental and laboratory sections revealed a decided disparity. The dental and laboratory sections had at least one T/3, (Technician, Third Class) in the tables of organization. The X-ray department had none, though the chief radiographer of the X-ray department of a general hospital required training and experience far above that signified by the rating of T/4 (Technician, Fourth Class).

Many commanding officers of hospitals recognized this disparity and used their headquarters, surgery, dental, or laboratory allotments to provide a T/3 rating in the X-ray department. This was done voluntarily in 59 general and 29 station hospitals in the European theater. When the low grades officially prescribed were adhered to, the effect upon the morale of these highly trained and efficient soldiers was harmful.

In February 1944, at the request of the Chief, Professional Service Division, the theater Chief Surgeon personally carried the following question to the Office of The Surgeon General:

> Why does the T/O for enlisted X-ray technicians of station and general hospitals not include as high ratings as other enlisted specialties?

The recommendation was added that the rating be the same as for surgery, dentistry, and other specialties. On 20 March 1944, the following teleprinter answer was received from Washington:

> Rules governing Tables of Organization do not authorize grades above T/4 for X-ray technicians. Recommendations for increasing these grades will be initiated by this office.

Very little effect from these recommendations was observed during the remainder of the war.

TRAINING OF X-RAY TECHNICIANS

Preliminary Training

The training that X-ray technicians had received in the Zone of Interior before they arrived in England was generally excellent. It had been carried out at several Army X-ray schools in the United States (p. 30). The courses, which were necessarily short, trained large numbers of men to perform essential radiographic procedures. Both theoretical and practical instruction was good, and, when the technicians were assigned immediately to active hospital units, they performed very well. On the other hand, as Dr. Cesare Gianturco (formerly Lieutenant Colonel, MC) pointed out in a postwar evaluation of this training, problems arose when the technicians graduated from these schools were assigned to units awaiting oversea orders and were kept inactive for long periods in staging areas. During these inactive periods, their recently acquired technical ability deteriorated rapidly.

That this deterioration could be prevented by the exercise of a little ingenuity was proved by a group of radiologists in hospital units which staged at Camp Barkeley, Tex. They had no teaching aids available for several months, but they built a wooden tube stand, which they used with an ordinary mess table to practice radiographic positioning. This practice, combined with lectures on radiographic theory, kept the technicians in the camp in readiness for oversea duty. As these radiologic officers showed, limited training could readily, and profitably, be provided for technicians at camps at which hospital units were inoperative for periods of time.

Training Overseas

The oversea training of X-ray technicians was a function of radiologists in all hospitals in the European theater. In February 1943, shortly after his arrival in the United Kingdom, the Senior Consultant in Radiology, ETOUSA, established the principle that radiography, which may be defined as the photographic representation of diagnostic evidence, was just as much the responsibility of the radiologist as was the interpretation of radiographs and the general direction of an X-ray department. Just as auscultation, percussion, and other clinical procedures were the professional responsibility of the internist and the surgeon, so the production of radiographs was the responsibility of the radiologist. It was only because, for practical reasons, certain phases of the radiographic procedure had to be delegated to the X-ray technician that the radiologist was relieved of the responsibility for personally positioning each patient and personally making all exposures.

This point of view was outlined in Colonel Allen's first annual report (1943) (p. 325), and it was emphasized by him throughout the war, formally, by means of meetings and conferences with theater radiologists, and, informally, by discussions with them whenever the opportunity arose.

Implicit in this point of view concerning the responsibility of the radiologist was the importance of good radiography. Also implicit in it was his responsibility for the training and continuous education of X-ray technicians. In his efforts to improve radiography and achieve maximum efficiency, Colonel Allen called attention to the following practical considerations:

1. The radiologist must always be a better radiographer than his technicians.

2. Whenever the situation permitted, the radiologist must spend as much time as possible in the radiographic room, giving practical instruction in positioning and in the general principles and technical practices of this specialty.

3. The radiologist must closely supervise the work of technicians in the darkroom, insisting that they adhere strictly to the specified timing of film development and the specified temperature of the developing solution.

4. Whenever it was feasible, technicians should be present when their films were read. This was an excellent plan for improving both the attitude of the technician toward his work and the quality of his radiographs. Technicians liked this form of instruction and found it most useful to have the radiologist criticize the technique used in special films in terms of changes in time, distance, and kilowatts, in order to improve contrast and detail.

5. Finally, the radiologist must conduct formal weekly classes in physics and in various aspects of radiography.

The Senior Consultant in Radiology seldom visited a hospital without spending from 15 minutes to an hour with the X-ray technicians. Regional consultants were instructed to do the same. These meetings were always pleasant and rewarding experiences. Radiographs were inspected and the functioning of the department investigated and discussed. There was no doubt that the classes and demonstrations described were helpful to the technicians as well as the radiologists and that they played an important role in improving the quality of radiography in the theater.

Some radiologists had excellent individual methods of training. At the 116th General Hospital, for instance, Maj. (later Lt. Col.) Linneus G. Idstrom, MC, built a miniature X-ray machine on panels as an aid to didactic fundamental training (fig. 127).

British training.—As noted elsewhere (p. 332), Colonel Allen arranged, through the chief radiologic consultant of the British Army, to send selected U.S. technicians to the X-Ray Technicians School at the Royal Army Medical College (fig. 128) for special instruction and also with the idea of overcoming the extreme resistance they had exhibited toward the use of British X-ray machines. Each course lasted a week. At first, the technicians attended in groups of six. Later, the number was increased to 12. In all, 79 keymen attended. Each group was billeted with British soldiers at the school in London and ate at their mess. The courses provided valuable general instruction and also brought about a much more favorable attitude toward British machines on the part of the technicians.

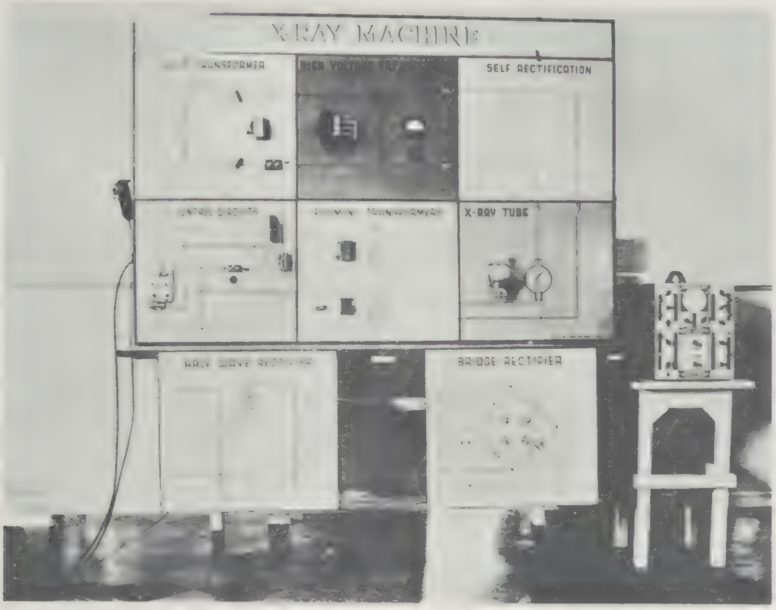

FIGURE 127.—Panel demonstration of wiring and function of self-rectified U.S. field X-ray unit designed for instruction of X-ray technicians. This model, which functioned at a harmless voltage, clearly showed primary and secondary windings and control and measurement of current.

EVALUATION OF WORK OF RADIOLOGIC PERSONNEL

The heavy workload of radiologic personnel is mentioned at intervals throughout this section. It was particularly impressive to this Consultant on his visits to the forward areas in Normandy in June and July 1944. During this period, the 2d Evacuation Hospital, for instance, averaged 100 patients per day for 28 days, and other hospitals were carrying equally heavy loads.

Statistics, unfortunately, are incomplete. Only quarterly reports were required of radiologists, on ETOUSA Form 320. These reports were received regularly from hospitals in the rear areas, but not so regularly from mobile hospitals in forward areas. The following statistics are based on the quarterly reports from January 1942 through June 1945 of 291 general hospitals, 288 station hospitals, 12 evacuation hospitals, 25 field hospitals, and 13 dispensaries.

The 1,561,047 X-ray examinations carried out during this period were divided as follows:

58,202 gastrointestinal examinations.
12,284 gallbladder examinations.
22,646 kidney examinations, plain.
11,796 kidney examinations, excretory.

FIGURE 128.—Class of U.S. Army X-ray technicians at British Royal Army Medical College X-ray School, 14–18 May 1945.

9,242 kidney examinations, retrograde.
357 encephalograms.
104 ventriculograms.
610 myelograms.

The remaining 1,445,806 X-ray examinations included examinations of the extremities and other areas to demonstrate bone injuries and disease, of the chest, of the sinuses, and of various areas of the body to demonstrate foreign bodies.

This heavy workload was borne in a most exemplary manner, the performance of both radiologists and technicians being of the highest quality. Repeated letters to this effect were received in the Office of the Chief Surgeon, ETOUSA, from commanding officers of both rear area and forward hospitals. Entirely typical is the letter of Col. Charles L. Baird, MC, Commanding Officer of the 5th Evacuation Hospital. He wrote:

> I never received a single complaint about the X-ray service during our entire operation in the ETO. I received many compliments for the service rendered by Captain Tainter, the technicians, and the good work that was done by the unit. The equipment, the solutions and the films never failed to give the desired results.

Errors and accidents were surprisingly few, but they did occur, and some of them, like the following, had extremely serious potentialities:

A recently occupied general hospital, just constructed by the British with ersatz material, was found to have many light leaks in the darkroom walls. It was simple and logical to borrow plaster of paris from the neighboring department of orthopedics to plug the leaks; obviously convenient to transfer the powder from its original paper container into an empty tin

which had formerly contained barium; and then to set the container, plainly labeled "Barium Sulphate," aside for future use to plug further holes. Finally, it was inevitable that the container should later be moved to the shelf containing other barium and should be administered to four men scheduled for successive gastrointestinal examinations.

Fluoroscopic examination on the first of these patients was unsatisfactory because the ingested opaque material was decidedly less opaque than usual, and more powder was added to the mixture. It was not until after the same difficulty had been encountered in the next three examinations and the fourth patient had complained, even more vehemently than the preceding patients, of the unpleasant taste of the drink that it was realized that something had gone wrong.

An investigation quickly revealed that the powder in the can was not barium and what had happened became all too evident. Immediate consultations were held with the chiefs of the medical and surgical services. In the test tube, dilute hydrochloric acid was successful in keeping the plaster of paris liquid, but successive films showed that the powder had formed a gastrolith in each of the four patients. In spite of the absence of obstructive or other symptoms, it was decided, on the fourth day, that gastrotomy would be safer than continued observation, and preparations for surgery were in train, when another set of films revealed that the gastrolith in at least one of the patients had begun to break up. Within the next several days, all of the patients passed all of the plaster, and none of them showed any ill effects from the experience.

This is, of course, an error that should never have occurred, and it is for that reason that it is recorded in this volume.[2]

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CHAPTER XII

Equipment

Kenneth D. A. Allen, M.D.

PROCUREMENT OF STATIONARY X-RAY MACHINES

In January 1943, during a visit to the Office of The Surgeon General en route to ETOUSA (European Theater of Operations, U.S. Army), Col. Kenneth D. A. Allen, MC, the Senior Consultant in Radiology, was informed that, because of the high percentage of breakage experienced in stationary X-ray machines previously shipped to England, virtually no more high milliamperage machines would be approved for the European theater.[1] The information meant that the many additional units required would have to be obtained from British sources.

When he arrived in England the following month, Colonel Allen further discovered from the Office of the Chief Surgeon, then in Cheltenham, Gloucestershire, that the supply of small X-ray machines was inadequate. The Chief Surgeon, however, had already approved the purchase of 337 machines from British manufacturers. Of these, 300 were of the 90-kv., 30-ma. type (fig. 129). The other 37 machines (fig. 130) were stationary units which could produce 100 ma. at 100 kv. for short exposures. Cassettes, film hangers, and X-ray film were also on order from the British.

During March and April 1943, the equipment situation in the United Kingdom was carefully surveyed. The survey included:

1. An estimate of British ability to deliver. At this time, it seemed that the machines and equipment on order could be produced by the scheduled date and that 200 hand-carry portable X-ray machines (p. 373) could also be delivered.

2. The attitude of the Finance and Supply Division, Office of the Chief Surgeon. The attitude of the personnel of this division was one of complete cooperation and considerable understanding of the radiologic problems. It was especially helpful in procuring items not on the T/E (table of equipment), such as those required in assembling an auxiliary mobile X-ray unit (p. 405).

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[1] A survey made later in 1943, at the X-ray repair depot in England, revealed that breakage in transport probably did not exceed 15 percent, considerably less than had been at first estimated, and that the damage was the result, for the most part, of poor packing. Generators suffered more breakage than the X-ray machines. A new method of packing generators, devised by the General Electric X-Ray Corp., greatly reduced breakage of generators; when the same method was followed in packing X-ray machines, they also traveled intact.

FIGURE 129.—British 90-kv., 30-ma., mobile (not portable) unit, of which 300 were purchased, was sturdy and dependable for work on a smooth, level floor.

3. Present and future equipment needs in the theater. At that time these needs were related to the preparation for future expansion.

The high hopes that had been raised as to British capabilities when this survey was made soon changed to disappointment. Production lagged far behind schedule. By the end of 1943, only 12 of the 37 stationary X-ray machines that had been ordered had been delivered. This made it necessary for station hospital X-ray departments to function with only 30-ma. mobile field units and also made it necessary to establish a policy of sending to general hospitals all patients who required gastrointestinal and other refined roentgenologic studies. At the end of 17 months, only 252 machines of the 90 kv., 30-ma. type had been received. Their delivery had required constant official prodding by the Procurement Section of the Finance and Sup-

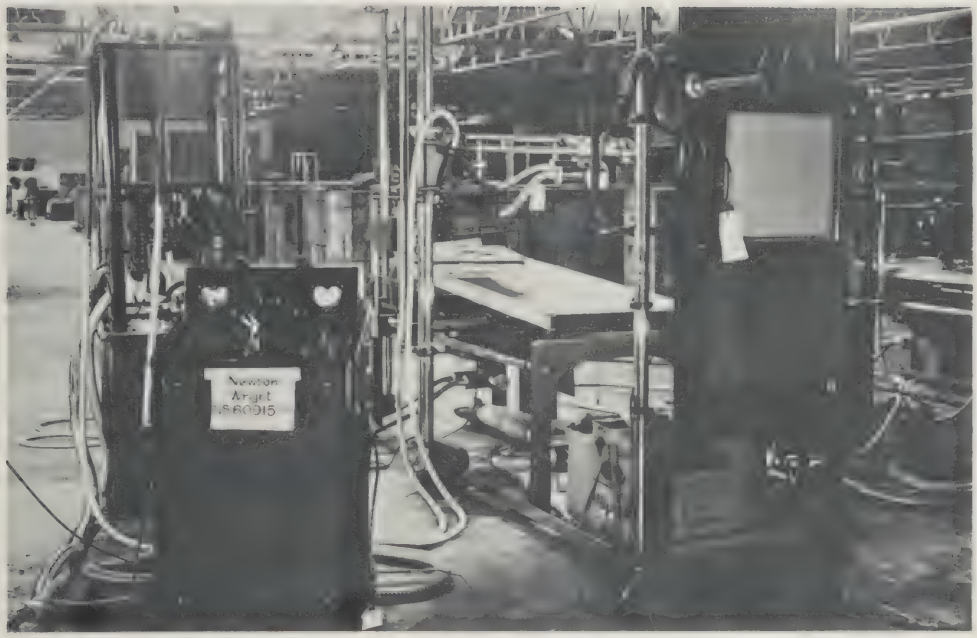

FIGURE 130.—Example of British stationary unit producing 100 kv., 100 ma. maximum for $1/10$ second only. Thirty-seven of these machines were purchased, of three different makes, the parts of which were not interchangeable.

ply Division, Office of the Chief Surgeon, and periodic unofficial contacts with the manufacturers by the Senior Consultant in Radiology. These contacts were possible because of his close liaison with the office of the chief of the Radiologic Service of the British Army (p. 330).

Shortages of equipment caused by failure of expected British deliveries were partly offset by rapid increase in U.S. production and deliveries. The Chief, Finance and Supply Division, Office of the Chief Surgeon, Col. Walter L. Perry, MC, and his successor, Col. S. B. Hays, MC, never questioned the necessity of the X-ray items requested. To them, the only problem was availability or procurability. Colonel Allen became, in effect, a member of that division as far as X-ray equipment was concerned. For his part, he constantly endeavored to insure economic and efficient use of all equipment allotted to hospitals and to insist that all material not in use, whether or not it was on official T/E's, be returned to the supply depots.

Allotment.—Because of the difficulties of procurement, all X-ray machines, whether stationary or portable, were personally allotted to hospitals by Colonel Allen in collaboration with the Finance and Supply Division, Office of the Chief Surgeon.

Because there were originally not enough stationary X-ray machines to supply all general and station hospitals, and also because there was such great variation in their quality, the Senior Consultant in Radiology, through

the Finance and Supply Division, allotted the most efficient machines to the general and station hospitals to which the more skilled and experienced medical officers in all specialties were to be assigned. This meant that many of these machines went to grouped hospital installations and to centers for specialized care. By June 1944, all general hospitals in the United Kingdom had stationary machines of some kind, and, by January 1945, practically all station hospitals were similarly supplied.

At first, no stationary machines, except a few from the North African Theater of Operations, U.S. Army, were shipped to the Continent, because of the transient status of the station and general hospitals there. By August 1945, plans had been completed for all general hospitals on the Continent to be equipped with these machines if they were to function in any location 90 days or more.

EQUIPMENT OF FOREIGN MAKE

By April 1943, it had become clear that in the European theater, the X-ray equipment provided would include no fewer than 44 models of X-ray machines, manufactured by 30 companies. Of these, 20 models were manufactured by six British companies.

Many U.S. radiologists and technicians were frankly reluctant to use the foreign equipment. Several plans were employed to overcome this attitude:

1. In an article in the 15 June 1943 issue of the *Medical Bulletin, Headquarters, Office of the Chief Surgeon, ETOUSA* (*1*) the Senior Consultant in Radiology pointed out that the critical supply situation made it necessary to use British equipment.

2. He made arrangements with Brigadier D. B. McGrigor, RAMC, Consultant in Radiology for the British Army, for training radiologists and technicians at the Royal Army Medical College, in order to introduce them to British equipment. Carefully selected keymen, about 12 in each group, received instruction in week-long courses during 1944 and 1945. The men were billeted at the college during the training period. The course consisted of both academic and practical training in the handling and use of British X-ray apparatus, chiefly the MX–1, MX–2, and MX–3 machines; the knockdown portable and Mobilax 90–90 "A" and "B" machines; and Solus 90–30.

3. The British manufacturers endeavored to standardize the stationary machines ordered by the U.S. Army, which were made by three manufacturers, but their efforts, while helpful, did not entail uniformity of technique or interchange of spare parts.

The hospitals in which the greatest adjustments had to be made in the use of this conglomerate equipment were among the first sent to the European theater, chiefly the 2d, 5th, 30th, 67th, and 298th General Hospitals; the 3d, 38th, and 152d Station Hospitals; and the 2d Evacuation Hospital.

4. A number of special meetings were held at which equipment was the principal topic of discussion.

On 7 December 1943, a meeting of all radiologists in the European theater was held in the British Institute of Radiology in London (p. 355). At it, the chiefs of supply, the procurement officers, and the radiologic consultants of both the British and the United States Armies discussed equipment problems with such frankness that thereafter there was increased understanding and cooperation between X-ray departments of hospitals and the Finance and Supply Division, Office of the Chief Surgeon. Similar meetings were convened in the base section headquarters in the spring of 1944.

Meetings were held with the radiologists and supply officers of the First U.S. Army on 10 February 1944 and with those of the Third U.S. Army on 30 May and 30 June 1944. At all of these meetings, equipment problems were discussed in detail. Other points stressed by Colonel Allen in his presentations at them dealt with improvising equipment that was not available and with setting up X-ray departments in tents.

Most of the meetings held in the winter and spring of 1944 were attended by CWO Claude G. Todd, USA, an exceptionally capable serviceman from depot M–400 (p. 401). He made many valuable suggestions, especially on maintenance of generators, electrical fixtures, and repair of X-ray equipment in the first echelon.

There were a number of reasons for the shortages of X-ray equipment in the United States at this time, in addition to general wartime shortages. Machines were required in far more than normal numbers for (1) the routine radiographs made on all draftees and inductees, (2) radiographs made in Army hospitals, some of which would probably not have been ordered in civilian life, (3) mass radiographic studies, and (4) radiographs made on combat casualties returned to the Zone of Interior.

In the article prepared by the Senior Consultant in Radiology for the *Medical Bulletin, Office of the Chief Surgeon*, ETOUSA, and published in June 1943 (*1*), the critical nature of the X-ray equipment situation was recognized. Colonel Allen wrote:

> X-ray equipment, especially machines, processing units, calcium tungstate screens, metal cassettes, radiographic tables, grids, Bucky diaphragms, lead protective material are all produced from critical raw war material. Therefore, in the United States, national regulation agencies have for many months completely controlled the output of machines to civilians, as well as to the Army. This control is already more stringent than it is in England.

In the remainder of this article, it was explained that because of the strict regulation of all material in the United States, compounded by transportation and shipping restrictions, it was mandatory that all X-ray machines and some other X-ray items (except those that accompanied medical units), be acquired in the United Kingdom. Materials critical in the United States were also at a premium in England, and X-ray equipment, especially machines, was difficult to procure.

Finally, it was pointed out in this article that machines which resulted from standardization of construction on the part of competing manufacturers,

even though many desirable features were lacking or reduced in number, were "better than no machines at all," especially if material and manpower were conserved at the same time. It was also pointed out that "A wide and equable distribution of a usable machine is preferable to an inadequate supply of more desirable models." The British-made machine did not necessarily please the British radiologists either, but the only adjustment required by both British and U.S. Army officers was that of the radiologist's technique to the machine available to him.

Technical Considerations

By relating technique to the limitations of the special machine, it was surprising what good results could be obtained. There was much experimentation at first, especially with machines without milliamperage control. To compensate for free milliamperage, the milliamperage second total was controlled by time change.

The British machines had larger focal spots than those to which U.S. radiologists were accustomed. The resulting reduction in detail was compensated for by increasing the distance of the tube from the film.

Lack of power was the greatest difficulty that had to be overcome, but even this lack could be compensated for as, for instance, in gastric examinations, by foregoing the use of the Bucky diaphragm.

These and other substitutions and improvisations somewhat affected the photographic quality of films but did not affect their diagnostic quality. Many medical officers, however, who were not radiologists believed, at first glance, that the radiographic quality was worse than it really was.

Standardization of radiographic techniques was achieved by using only the fundamental positions explained and illustrated in the manual of X-ray positioning prepared by the Senior Consultant in Radiology. Textbooks on radiography (p. 357) were supplied to radiologists to guide them in specialized work which required positions other than those standardized in the manual.

Only one X-ray department in the theater, at the 109th Evacuation Hospital, utilized the optimum voltage technique. All the other radiologists voluntarily selected the contrast method.

It was found in the European theater that very heavy development was necessary, though a single specific cause was never identified. Undoubted contributing factors were (1) chemicals and minerals in the available supplies of water, and (2) weak or impure developing and fixing powders. That the composition of the water was one of the factors was demonstrated by the fact that the use of distilled water diminished the development time required for equal densities. It did not, however, correct the difficulty.

PROCUREMENT OF PORTABLE X-RAY MACHINES

By March 1943, it had become apparent that some sort of portable X-ray machine was mandatory in the European theater, since many casualties would need bedside X-ray studies. A machine was required which could be taken down and carried by hand to wards in tents or buildings separated by rough walks or paths. Mobile machines were not satisfactory for this purpose. The British machine deteriorated rapidly when moved over cement walks. The U.S. Army machine (item 96085 in Medical Department Supply Catalog, 1943, used for field fluoroscopy, roentgenography, and superficial roentgenotherapy) had small casters and was difficult to move.

When Colonel Allen found that satisfactory knockdown, hand-carry portable machines could not be expected from the United States, he requested procurement on 23 March 1943 of 200 British MX–2 type portable machines (figs. 131 and 132). He had observed the efficient performance of these machines under heavy duty in British hospitals in the North African theater.[2]

When the order was placed, there was every reason to believe that these machines would be delivered according to the contract, but again there was disappointment. By 25 June 1944, only 60 had been delivered, and by the end of the war fewer than 100 had been received.

In fairness to British manufacturers, it must be remembered that they were operating under highly abnormal conditions. The country had been at war for almost 4 years and had been subjected to devastating aerial bombardment. The manufacturers were severely handicapped by shortages of raw material and of suitable manufacturing facilities, including manpower. Finally, both production and deliveries were delayed because of the heavily overtaxed British transportation system.

During the summer of 1944, another effort was made to procure portable machines from the United States but it, too, was unsuccessful. It is believed that failure to supply Service of Supply hospitals promptly with hand-carry portable machines was the only serious deficiency experienced in X-ray equipment during the war.

The lack of portable machines was compensated for in large measure by improvising dollies of various types (p. 380) and converting the airflow U.S. table for portable use. Late in the war, half a dozen French portable machines were recaptured from the Germans and rendered usable by U.S. X-ray departments.

Because of the difficulty of procurement of this important item, Colonel Allen recommended on 27 May 1943 that the Medical Supply Catalog include a satisfactory hand-carry portable X-ray machine. No action was taken on this recommendation during the war.

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[2] A distinct advantage of the British X-ray machines was that they were built for 50-cycle electric current, whereas U.S. units were all designed for 60 cycles. The U.S. units were therefore inclined to heat unless their transformers were provided with very large iron cores. Cycle changers, however, were difficult to procure and were not entirely satisfactory when used.

FIGURE 131.—Watson portable X-ray apparatus, type MX–2. Top, ready for use. Bottom, packed in carrying cases, which contain everything except folding stand for control unit.

FIGURE 132.—Radiographic examination of head, X-Ray Section, 7th General Dispensary, London, 1942. The portable equipment is of British manufacture.

PROCUREMENT OF PROCESSING EQUIPMENT

As early as July 1943, it was recognized that a shortage of film-developing capacity existed in the European theater. As a result, attention was focused upon the shortcomings of the X-ray field processing unit for darkrooms (item 96115, Medical Department Supply Catalog, 1 June 1943). This particular unit had several highly undesirable features. One was that it required 2 feet of space around it on all sides in order to service it. A unit so designed that the refrigeration unit was outside the darkroom and the water bath inside the room would have been more satisfactory.

A second undesirable feature of this machine was that the 50-cycle current available in the theater did not properly energize it since it was built for 60 cycles. The Senior Consultant in Radiology and many of his asso-

ciates believed that the developing and functioning capacity of this unit should be expanded. Expansion did not necessarily mean enlarging the water bath; it was entirely practical, except in hot climates, to place fixing solutions outside the water bath, if necessary.

To accomplish this objective, British manufacturers were asked to produce 150 stainless steel insert tanks of 10-gallon capacity. On 17 August 1944, 160 inserts of 15-gallon capacity were received, but the material of which they were constructed had been changed, without consulting U.S. procurement personnel, from stainless steel to galvanized iron. As a result, before the inserts could be used with processing solutions, their interiors had to be coated with acid-resisting paint, which had to be renewed every 30 days.

At this point, 300 enamel-lined insert tanks were requisitioned from the United States. They began to arrive in 90 days and doubled the capacity for processing films in the hospitals to which they were supplied.

PROCUREMENT OF ACCESSORY EQUIPMENT AND FACILITIES

By 17 December 1943, after earlier visits to the field and evacuation hospitals of the Fifth U.S. Army in combat on the Italian front, it became evident to Colonel Allen that the T/E for X-ray items was deficient in certain respects. This conclusion was supported by an inspection of the X-ray departments of the same types of hospitals in the First U.S. Army, which was then in the United Kingdom. Particularly notable were deficiencies in darkroom tents, cassettes of all sizes, film developing hangers, and processing (insert) solution tanks. Upon Colonel Allen's recommendation, the Chief of the Finance and Supply Division, Office of the Chief Surgeon, recommended increases in these and other items. Later experience showed that darkroom tents had to be doubled in number and all the other items trebled. This augmentation was duly accomplished and, by the fall of 1944, each of the Armies in the European theater was authorized to increase the T/E's for field and evacuation hospitals accordingly.

The same difficulties arose with British-supplied accessory equipment as had arisen with the British X-ray machines. By the end of 1943, there had been no delivery of some items. At this time, of 24,000 film development holders on order, only 408 had been received. Similarly, only an insignificant number of the 4,620 cassettes contracted for had been delivered. Most of those which had been received, moreover, had no screens and were therefore useless. These delays forced the Finance and Supply Division of the Chief Surgeon's Office to direct its attention back to the United States in an effort to procure sufficient equipment to supply the hospitals which would be stationed on the Continent after D-day.

CRITIQUE OF EQUIPMENT

Darkroom Tents

The darkroom tent furnished in the European theater (item 96175, Medical Department Supply Catalog, 1943; X-ray field unit, tent, darkroom: used for fluoroscopy and film processing) was not satisfactory for two reasons: It was not lightproof, which meant that it could be used only under other cover, and it had inadequate ventilating facilities. Some improvement in ventilation could be gained by reversing the ventilator, so that air would be forced from, rather than into, the tent, but this was a makeshift, inadequate arrangement. Experience proved that each evacuation hospital and each general hospital set up in tents, should have two darkroom tents, one to be used as a darkroom and the other for fluoroscopy.

Grids

On 26 March 1943, the Senior Consultant in Radiology requested the procurement of 125 British Lucidex grids, on the ground that all X-ray departments should have a constant supply of this accessory for routine and bedside radiography. Experience indicated that stationary grids would be expendable in mobile hospitals in forward areas at the rate of 2 or 3 a year. The British grid was particularly durable and flexible and would have been highly desirable but, by the end of hostilities, only 17 of those on order had been delivered.

Tables

Throughout the war, excellent and dependable service was given from both types of table units supplied in the European theater (item 96145 in the Medical Department Supply Catalog for 1 June 1943, X-ray field unit, table unit: for fluoroscopy, foreign body localization, and roentgenography; item 96215, X-ray field unit, fluoroscopic, foreign body localization, complete: with table unit). Experience indicated, however, that it would be advantageous if both tables were of the tilt variety and if each had a small, light, strong Bucky diaphragm. Another improvement would be to change the lock handles of the movable apparatus on item 96145 to the opposite side of the table.

Nearly all X-ray departments improvised light, radiolucent tabletops of plywood or old plywood doors. These were dropped below the table level by angle iron braces, to permit sufficient room between a patient in the lateral position and the fluoroscopic screen.

The foreign body localization appendage was a superb and sturdy piece of equipment but it was too slow and cumbersome for wartime use.

Driers

The drier and loading bin combination (item 96055 in Medical Department Supply Catalog, 1943; X-ray field unit, drier, and loading bin combination: complete with air circulator, for field processing unit), which was a necessary item for all hospitals, gave excellent service. Experience showed, however, that the drier was more effective when it was used outside the darkroom in circumstances in which it was impracticable to carry the large type air vents provided for it.

Experience also showed that some changes in this combination item would have made it more useful:

1. The top surface of the loading bin should be completely smooth.
2. The drier should be a separate item from the loading bin, so that forward area hospitals, if they desired, could be allotted this item without the loading bin, which constituted two-thirds of its weight. The lead-lined chest (item 96205, Medical Department Supply Catalog, 1943; X-ray field unit, chest, film, X-ray) fulfilled the requirement for film protection in forward hospitals. The loading bin was therefore not absolutely essential. The lead-lined chest was an indispensable item, especially in forward area X-ray departments, but it was a heavy piece of equipment and would be improved by a mobile base.
3. The drier was 100 percent more effective when it was used with closed drying racks at each end. These racks had to be improvised.

Generators

During his visit to the Mediterranean theater in the fall of 1943 (p. 419), and in the course of inspections of tented X-ray departments in the European theater before the invasion, Colonel Allen observed the operation of the gasoline-powered electric generator (item 96060, Medical Department Supply Catalog, 1943; X-ray field unit, generator, gasoline, electrical: complete in chest). It could not be relied upon to run for more than 10 hours out of the 24, and variations in gasoline octane content and lubricating oil viscosity made its operation uncertain at any time. The solution of this problem was that two generators instead of one be furnished to each unit of each field hospital. The recommendation was approved and was implemented as far as availability permitted.

In the fall of 1944 and the spring of 1945, many hospitals were supplied with central electric power generators. Experience promptly indicated, however, that each X-ray department should have allotted to it, in addition, an emergency 5-kv. generator designed for the workload and with more versatile carburation. It also became evident that, as an integrated part of its manufacture, adequate provision should be made for repacking the generator since it had to be moved repeatedly. No such provision was made during the war.

Methods of procuring the greatest service from the 2.5-kw. generators were the subject of endless discussions. Distribution of the power by impro-

vised switches, and the length and size of wire runs (table 11, p. 441) required study and ingenuity. Radiologists were urged to use central power whenever a large hospital generator was available and to use local civilian electric power whenever it was available in the proper form. The field unit machines wired for both 115 and 230 volts permitted more frequent utilization of civilian power.

As these remarks indicate, the X-ray generator supplied to the European theater was not satisfactory. It was undependable, inadequate, and not readily adaptable to temperature changes, inclement weather, and various types of gasoline and oil. Much credit is due the radiologists and technicians in forward hospitals and auxiliary mobile X-ray units who had to derive their power from it. It was only by exercising great ingenuity and infinite patience and by arduous work that these X-ray departments continued to function.

Cassette Changers

Observation in the European theater indicated that the cassette changer (item 96117, Medical Department Supply Catalog, 1943; X-ray field unit, processing unit, auxiliary wash tank) had no place in an oversea Army. It was a bulky, intricate, fragile accessory. Stereoscopic examinations of the chest were valuable, but they did not justify the weight and fragility of a plate changer, which could have been replaced by a sturdy single upright cassette holder. Most hospitals improvised this type of equipment.

Illuminators

The experience in the European theater showed that glass front radiographic illuminators of the fluorescent type (item 60400, Medical Department Supply Catalog, 1943; illuminator, radiographic: used singly or in batteries of two or more for viewing films up to 14 by 17 inches) were valuable and, in spite of breakage, were justified in the equipment of oversea armies. In addition, a collapsible illuminator, with a rolled, flexible light diffusion screen should have been provided. This type of screen was found among captured German equipment (p. 398).

IMPROVISED EQUIPMENT

Even before the combat experience in the European theater, the importance of, and necessity for, improvising radiologic equipment to meet particular situations in wartime were clearly evident. Beginning in 1942 and continuing until the end of the war, many pieces of X-ray accessory apparatus were improvised. Those which proved most practical were described in chain letters that were passed from hospital to hospital. Whenever prac-

tical, models of the items accompanied the descriptive letters. If the models were too large to be circulated, photographs and designs were enclosed.

This plan worked very well in 1943. By 1944, there were too many hospital units in the theater for it to be continued, and other methods of disseminating information had to be employed. The improvised items were discussed at various meetings and conferences, and details concerning some of them were published in the theater medical bulletin. Information concerning them was also disseminated by word of mouth by the Senior Consultant in Radiology and by the regional consultants.

Personnel of ordnance units could always be relied upon to give assistance in turning and joining improvised X-ray equipment made of metal.

The important items of equipment which were improvised are described in this chapter. The information, and the inferences permissible from it, should furnish useful guidance in planning equipment for Army hospital X-ray departments and auxiliary mobile X-ray units in preparation for a future war.

Compression band.—When the patient was examined on the litter (a practice found increasingly useful as the war progressed, both to spare him and to conserve manpower in the X-ray department), immobility was improved by the use of a compression band. This was improvised by attaching to the litter poles the metallic supports from the cables of Picker field unit No. 9620500 and fastening them to a flannel band. Wooden blocks were used for fixation and adjustment.

Vertical cassette holders.—Adjustable wooden frames were used by many radiologists to improvise vertical cassette holders. Some attached a plywood tunnel to the back of the fluoroscopic screen of the British Solus table, about 100 of which were used in the U.S. Army. Another excellent holder was made by attaching a simple metal frame to the vertical carriage of the Picker field unit (fig. 133).

Vertical fluoroscope.—The airflow X-ray unit (item No. 96215) was designed for radiography and fluoroscopy in the horizontal position. It was readily converted for vertical fluoroscopy and radiography by resting it on one end and adding appropriate pulleys and counterweights. The improvisation was suggested by Maj. (later Lt. Col.) Joseph G. S. Weber, MC; Capt. (later Maj.) Robert L. Scanlon, MC; and Sgt. J. O. Plenger, at the 196th General Hospital.

Portable X-ray machines.—Portable X-ray machines, as already mentioned (p. 373), were not available in the theater, but bedside examination was often necessary. Excessive and harmful vibration was inevitable when small-wheeled units were pushed for long distances, often over rough ground. The problem would have been at least partly solved if the new type units (Nos. 9608510 and 609010), with large pneumatic wheels, had become available in sufficient numbers early enough for universal distribution. They did not. The difficulty was therefore met by placing the machines in use on dol-

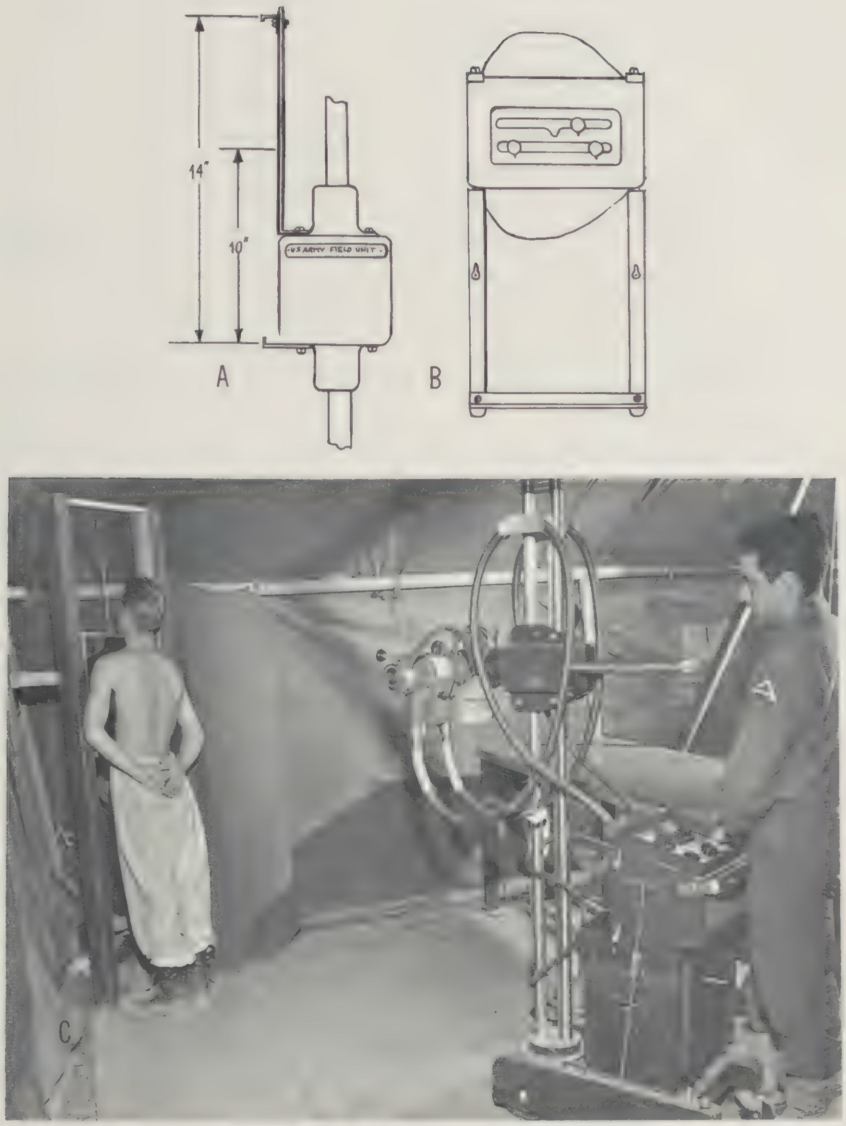

FIGURE 133.—Improvised vertical cassette holder. A, B. Diagrams showing metal bars added to Army field unit on vertical carriage of mobile base. C. Practice demonstration of improvised equipment in tented hospital (27th Evacuation Hospital), France.

lies with large pneumatic wheels obtained from litters or wheelbarrows (fig. 134). When the airflow machine (No. 96215) was used as a portable unit, frames such as freight dollies facilitated the transportation of the head and control stand to the bedside, as suggested by Lt. Col. Manuel Horwitz, MC,

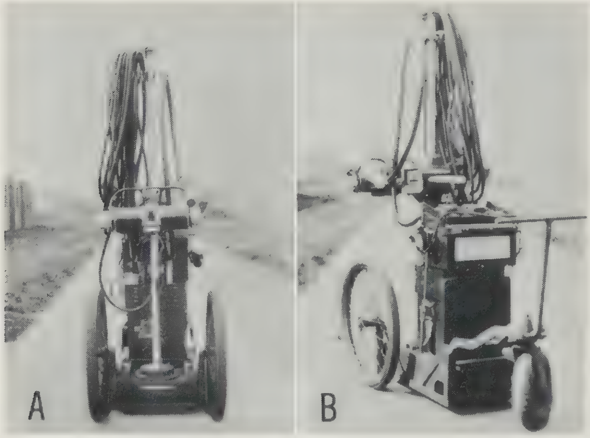

FIGURE 134.—Improvised method of increased portability of X-ray equipment. A. Front view of Army field unit mounted on equipment constructed by Quartermaster, Third Echelon Motor Maintenance Unit, from scraps of angle iron, round steel stock, and sheet steel. The two large rubber-tired wheels were taken from Medical Supply Item No. 99175 and the rear wheel from a wheelbarrow. B. Machine viewed from rear.

and Capt. Harrison F. Harbach, MC (fig. 135). Other methods of making portable units were also devised (fig. 136).

In spite of all the ingenuity manifested, no improvisation proved efficient enough to replace a true knockdown, hand-carry portable X-ray machine. Each general, station, and evacuation hospital, and each auxiliary mobile X-ray unit, should have had one. Even when the large pneumatic-wheeled field unit was brought to the bed, it often could not be moved close enough to it for satisfactory use.

Tube rail platform.—To insure parallelism between mobile X-ray machines and radiographic tables, old bedrails (fig. 137) or other metal or wooden tracks were placed under the wheels. This device also eased the movement of the machine on a rough floor or on bare ground. On some occasions, when a larger surface was desired, wooden platforms (fig. 138) were constructed and placed alongside the X-ray tables; a surface was thus provided on which the machines could be maneuvered. Some radiologists thought that these platforms were more useful than tracks, in that, without moving the patient, they made it possible to take lateral radiographs of both extremities.

Tube adapters.—Tube adapters for cystoscopic tables were improvised by cutting pieces of 5-sheet plywood and fastening them to the tube arms and the tubes. Some adapters were constructed of metal by personnel from the hospital utilities section or nearby ordnance shops.

FIGURE 135.—Airflow X-ray unit converted to use as portable bedside unit. A. Machine placed on ordinary warehouse handtruck in such a manner as to produce a balanced unit, easily transported over rough ground from ward to ward. Wooden frame, supplied with small casters readily obtained from other equipment, was built around base of machine. B. Converted machine in use at bedside. Note that body of truck is low enough to fit under bed.

Cones.—The cones issued to mobile X-ray field units were not small enough for sinus or mastoid radiography. Many were therefore improvised from stove or water pipes, shell cases, or bazookas. When two or more standard cones of Army field unit No. 96085 were available, an efficient cone could be made by joining them together with solder or adhesive tape (fig. 139).

Serialographs.—Several types of serial gastric radiographs were made possible by a simple improvisation, the use of the principle of lead-covered tunnels (fig. 140). The radiographs could be taken in either the upright or prone position. This technique was useful only in hospitals with machines powerful enough to make the exposures in $\frac{1}{5}$ sec. or less. Examination of the stomach was discouraged in hospitals in which there were only low-powered machines. Colonel Allen constantly emphasized that roentgenograms of the stomach should be made without grid or Bucky diaphragm;

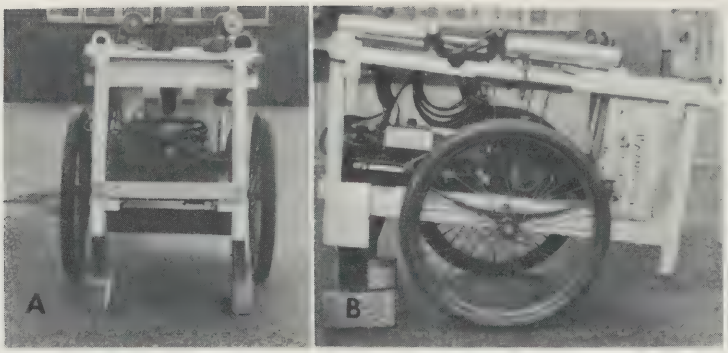

FIGURE 136.—Dolly used to increase portability of MX–2 Watson portable unit. A. Front view. B. Side view.

when they were employed, no machines were available sufficiently powerful to stop motion of the margins of the stomach by $\frac{1}{10}$ sec. exposure.

Sinus boards.—Sinus examination was facilitated by using the Sweet localizer tunnel as an angle board after two of its legs had been removed. Another sinus improvisation, suggested by Lt. Col. Earl H. Gray, MC, at the 30th General Hospital, was the substitution of a cassette holder for the fluoroscopic screen of the Army field table No. 96145 (fig. 141). This plan permitted radiography of the head in all positions at a fixed focal film distance. It was thought that this improvisation would also provide a simple technique for encephalographic studies in oversea neurosurgical centers.

Illuminators.—Several types of illuminators were improvised to supplement the inadequate supply of these necessary items. One of them (fig. 142), made at the 2d General Hospital by Capt. (later Maj.) Baird D. Jay, MC (*2*), was particularly practical because it did not require glass as the light-diffusing surface and it could be built with available lumber. This same basic design could also be used as a folding illuminator.

The entire inside surface of the illuminator, which was painted a flat white, was illuminated by an indirect source. The surface reflected the light diffusely through the film and provided, in turn, a bright blank surface against which the image stood out clearly.

The sloping back of the illuminator was the main deflecting surface. Two incandescent bulbs (50 to 60 watts), mounted high in the view box, with a 5-inch baffle to protect the viewer's eyes, provided the main source of light. Two $\frac{3}{4}$-inch holes drilled high in the sloping back, near the light bulbs, provided ventilation but did not cause glare. Supports for suspending the film were mounted near the lower edge of the baffle. The entire item stood 22 inches high and was 15 inches wide and 6 inches deep.

Auxiliary drying equipment.—Practically all X-ray departments needed additional film-drying capacity. The drier provided by the Army did not afford the necessary space to keep abreast of the volume of radiography

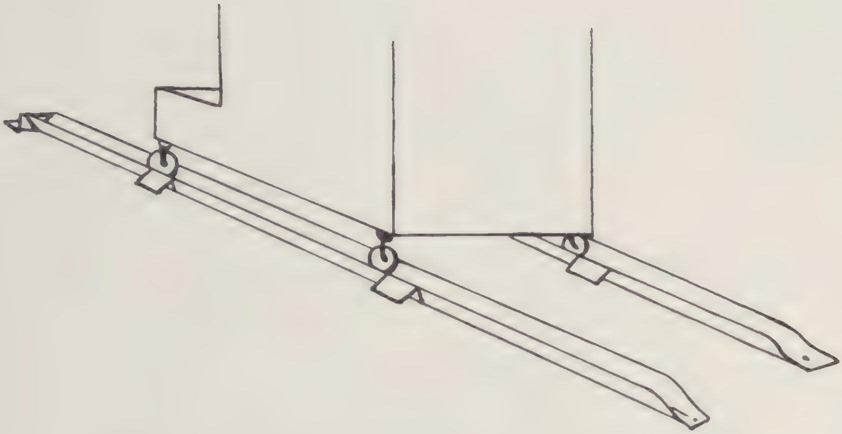

FIGURE 137.—Bedrails used with Watson or Solus X-ray units.

necessary in active warfare. It was the usual practice to place a box or frame at one end of the Army field drier, so that films could be dried by inflowing or outflowing air (fig. 143). If still more drying space was needed, as it often was in time of stress, films were hung on wires, as suggested by Col. Charles L. Baird, MC, Commanding Officer of the 5th Evacuation Hospital. The large air conduits in and out of the Army drier shortened drying time but were too bulky for field use. In addition, it was found that films dried much more rapidly by improvised techniques than in the drier itself.

When Colonel Baird was asked, in March 1959, for additional details about this improvisation, he replied: "I recall ordinary cord being run from pole to pole or tree to tree and films clipped on to dry. They were waving in the air, and they curved a little bit, but Tainter [Capt. Eugene G. Tainter, MC] flattened them out somewhow; I suppose his technicians used boards."

Headrests.—Several types of headrests were improvised for lateral radiography of the cervical spine (fig. 144). Their use to immobilize the head made the difference between radiographs of average quality and superior films which showed minute, easily overlooked, pathologic conditions. One of these headrests, made for use with the standard cassette changer, consisted of two triangular pieces of wood that fitted into the slides of the changer and could be adjusted to the patient's head. Some radiologists simply inserted a pillow between the patient's head and the cassette.

Stereoscope.—Stereoscopes were improvised in several ways. One was made by attaching mirrors to a sliding block between two illuminators (fig. 145). A hand stereoscope was made by using a set of four mirrors. An excellent stereoscope was designed by Lt. Col. Harry A. Miller, MC, at the 159th General Hospital.

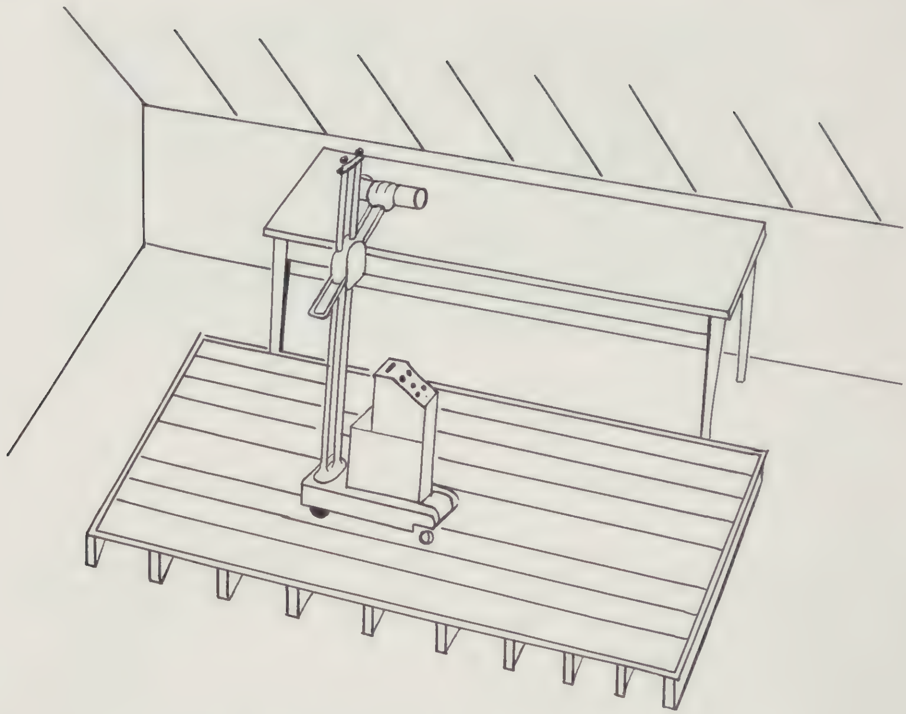

FIGURE 138.—Wooden platform built to use with Army field unit.

Motor-driven Bucky diaphragm.—The upright Bucky diaphragm devised by Maj. (later Lt. Col.) James B. Haworth, MC, at the 46th General Hospital proved valuable for special studies on patients who could not be positioned in the usual manner on the X-ray table (fig. 146). It was made from an Army field unit grid, of the type supplied with the Army field X-ray table units, and a 6-volt motor from an electric windshield wiper. The completed item, including the batteries which furnished motive power for the grid, weighed 25 pounds. It measured 20 by 24 by 5 inches, and was entirely self-contained. It was used either on an ordinary table, in the horizontal position, or vertically, suspended on a pair of guide rails and counterbalanced for ease of operation.

The apparatus included an auxiliary circuit designed to light a small flashlight bulb when the diaphragm was in operation and to extinguish it when the apparatus was cocked. The light served as a warning signal only. It was necessary, since the mechanism was completely enclosed, to prevent exposures on the reverse travel of the Bucky, which was somewhat uneven. On normal travel, the Bucky moved smoothly and did not make gridlines. A simple set of contacts, which varied the voltage supplied to the motor, regulated the speed of travel. The return of the Bucky was at a constant speed, regardless of the setting used on the radiographic travel.

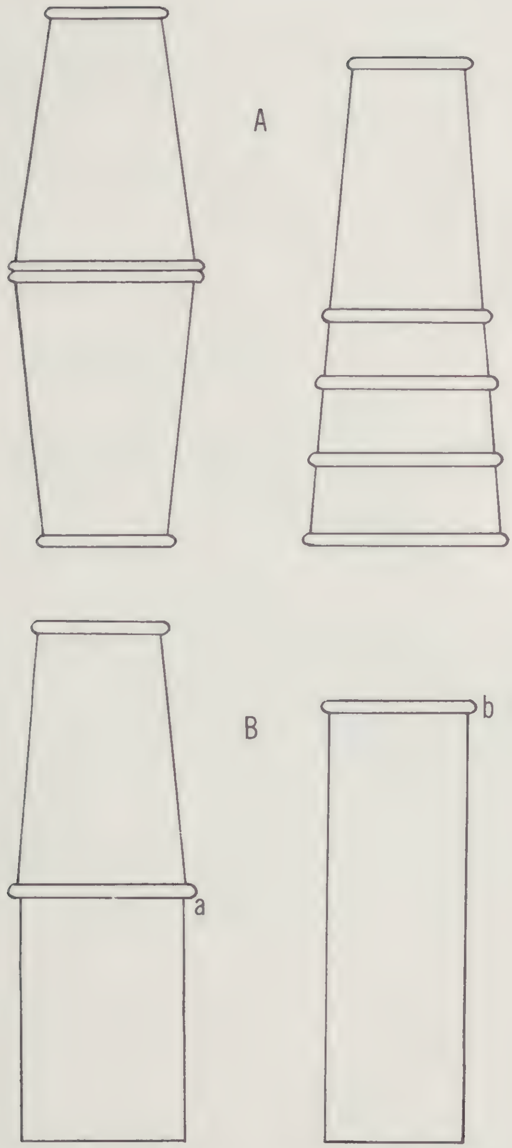

FIGURE 139.—Auxiliary cones. A. Cones held together by adhesive tape. B. Same, with wire rim soldered to 2-inch pipe: Solder (a), and wire rim soldered to pipe (b).

The components of this useful piece of apparatus demonstrate that it required ingenuity rather than elaborate materials to construct the improvised X-ray equipment used in World War II. In addition to the grid and motor, the necessary materials included: a set of bronze gears from a dis-

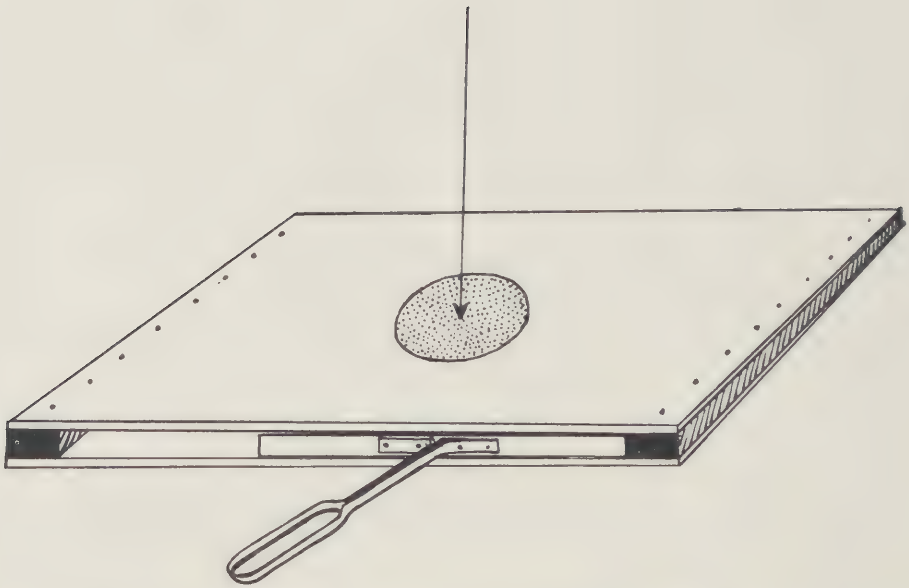

FIGURE 140.—Improvised serialograph for serial gastric radiography. Four exposures were made by 8- by 10-inch cassette in Sweet localizer tray. Materials consisted of sheet lead on 3-ply plywood.

carded field telephone; a shaft ¼ by 18 inches; two sheets of Masonite or plywood, 20 by 24 inches; a sheet of aluminum or sheet metal, 24 by 24 inches; a single-pole, double-throw switch; a small solenoid relay from a doorbell buzzer; a rotating solenoid switch, obtainable from any clock operating on direct current; a piece of oak 1 by 4½ by 88 inches; and small hardware, such as wood screws, small bolts and nuts, and sheet brass.

When Major Haworth was queried, 15 years after the war, as to the correctness of the foregoing description of his motor-driven grid and was also asked how he obtained the necessary windshield wipers, he replied:

Your recollection concerning the motor-driven grids installed in two of my nine army field units in the 46th General Hospital at Besançon, France, is very nearly correct. The first such unit was actually developed while we were located in the hospital center near Oran, Algeria, about February 1944. The second unit was made at Besançon, about September, 1944. The windshield-wiper motors, of French manufacture, appeared mysteriously in the department, on each occasion, one or two days after I had mentioned casually the need for such a motor. I suspect that I was wise in failing to inquire into the source from which the motors were procured. It is probably a coincidence that one of my sergeants (T. Sgt. Walter Radtke) was famous throughout the 46th General Hospital for his skill in the exercise of that useful military maneuver known as the Moonlight Requisition.

Other improvisations.—Among the other useful improvisations in the theater were protractors of simple design to denote the angulation of radiographic tubes (fig. 147), film trimmers to round corners of radiographs

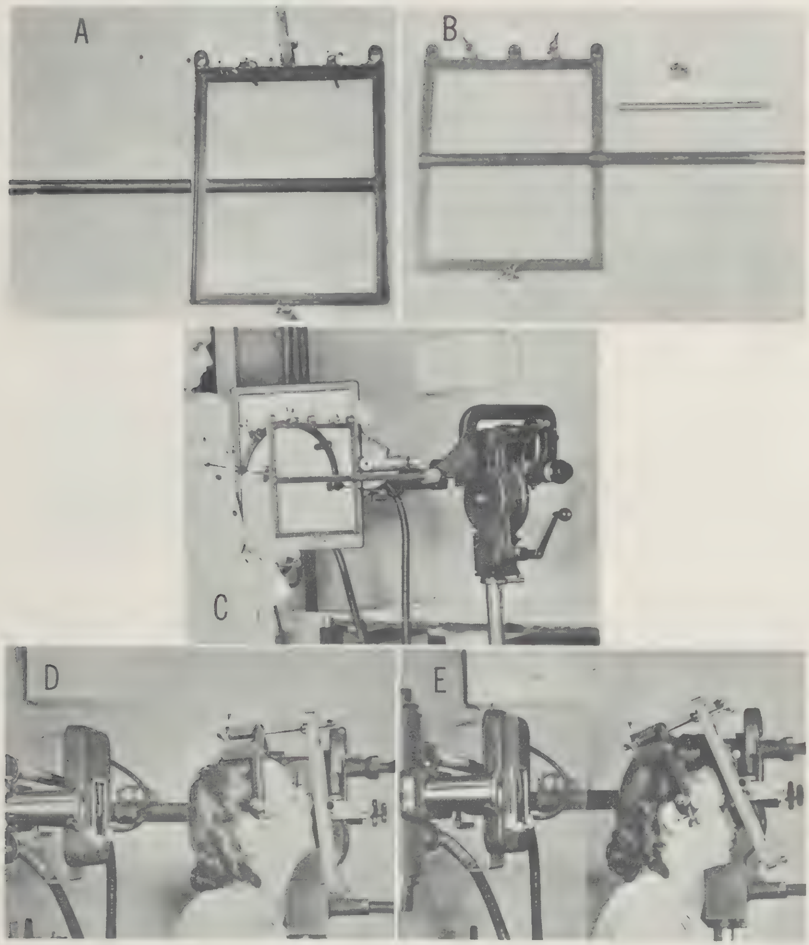

FIGURE 141.—Adaptation of Army field unit for examination of paranasal sinuses by substitution of cassette holder for fluoroscopic screen. A. Front view, showing right angle iron strips welded into frame sized to fit 8- by 10-inch cassette. Frame is welded to hollow metal tube which supports it; cassette is held in place by spring clips. B. Rear view. C. Device attached to field table, after fluoroscopic screen has been removed. Note head clamp attached to supporting column. D. Patient in Waters position. E. Patient positioned for examination of frontal sinuses.

(fig. 148), a technique of producing duplicate films for teaching purposes, and laminographs of various types.[3]

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[3] During the preparation of this volume, a letter received from Dr. (formerly Lieutenant Colonel, MC) Burton W. Trask contained, among other items, a list of improvisations he had personally participated in. The pertinent portions of the letter are appended, to illustrate what one officer's ingenuity could accomplish in the absence of conventional items:

1. We were about to open an X-ray department in England. Our lead letters had been bartered to another hospital for something, I know not what. I had in my X-ray Dept. a Chicago

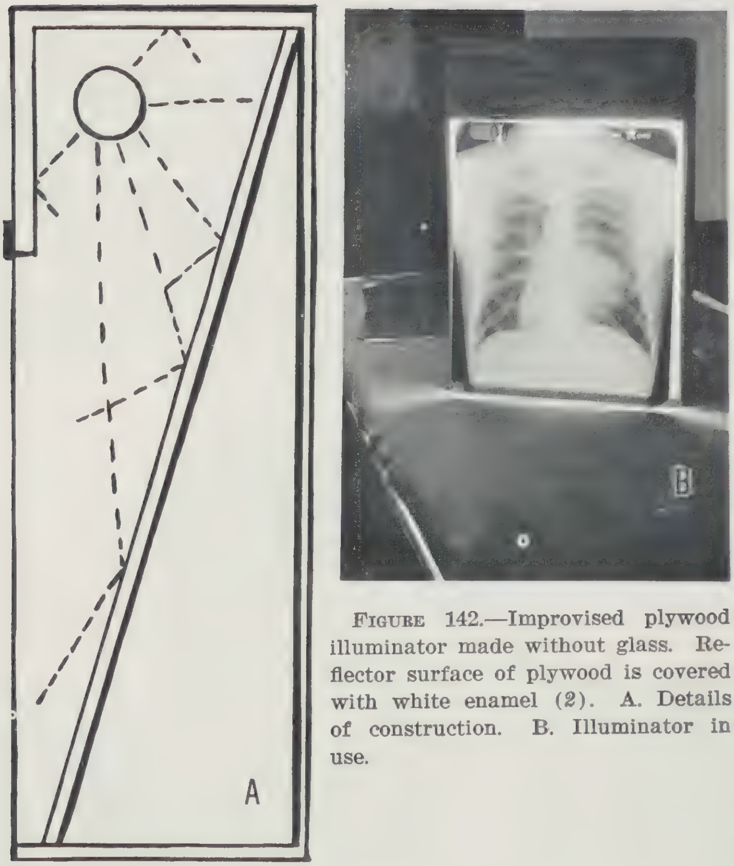

FIGURE 142.—Improvised plywood illuminator made without glass. Reflector surface of plywood is covered with white enamel (2). A. Details of construction. B. Illuminator in use.

commercial artist and window-trimmer. I told him to design some lead letters and numerals and make patterns and all of the men would spend the remaining time making lead letters and numerals until the hospital opened. The R's and L's were to be extra large. We did accomplish that feat. At that time there were no extra large lead numbers and letters in the UK [United Kingdom]. Today they still use the same large R's and L's in the service. Up to that time all had been small.

2. We also made a pass box to take cassettes in and out of the darkroom without turning on the lights. I had them labeled *In Exposed* and *Out unexposed.* That idea is used today.

3. In England we tried intravenous gallbladder dye by the oral route. Not too successful. Too many reactions. The British drugs are not as good as the American.

4. Another time in England I noticed that the ground around the X-ray Dept. floor was higher than the floor outside. One day water came in. Slight. I ordered everything off the floors. The equipment was to be placed on concrete piers and the film to be placed on mess tables British. Later we had a real rainstorm, a cloudburst. Water came into the X-ray Dept. and before it began to run out it reached within ½ inch of the top of the piers. I had saved the Army at least $15,000 in supplies and equipment and prevented the breaking up of the hospital X-ray unit. The deluge would have ruined the X-ray machines and the film, at that time short in England.

5. The Army had a urological table without an X-ray tube and generator. I suggested that an adapter be made and the Army field unit and tube be fitted to the tube and urological table. It worked.

6. In Germany, the powerlines were weak and the portable machine would not work. By lowering the amount of the milliamperage the Army X-ray machine could be made to perform; that without the circuit breaker interfering.

7. For the nameplate of the hospital we would have the dog tag machineman write out the hospital designation. Then we would file off the back of the dog tag numbers, making the stamped portion porous. We gave the designation of the hospital in this fashion.

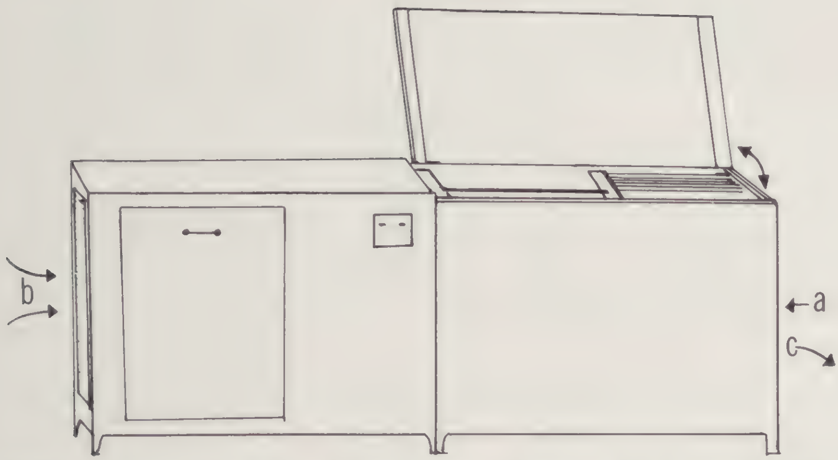

FIGURE 143.—Auxiliary drying bin, made of wood: Open end (a); movement of air in and out of bin (b, c).

Protective techniques (p. 334), improvised apparatus for cardiokymography (p. 463), and techniques of marking films (p. 338) are discussed elsewhere, as a matter of convenience.

FILM PROCUREMENT AND USE

Estimates

In December 1943, at the request of the Finance and Supply Division, Office of the Chief Surgeon, film requirements for 1944 were estimated. Since there was no information as to when the invasion of the Continent would take place, Colonel Allen had to assume that it would occur as early as March or early April. In 1943, 29 hospitals in the theater with a bed occupancy of 8,700 had used 24,128 dozen films. The currently estimated bed occupancy for the United Kingdom, plus occupancy in the anticipated assault area for 1944, was 358,000, almost 42 times greater than for 1943. On this basis, Colonel Allen requested 1,008,000 dozen films. The Office of The Surgeon General finally approved a figure of 850,000 dozen, adding that the original estimate for ETOUSA exceeded the contemplated use of films in all theaters of war in 1944.

Supply

Until late December 1943, supplies of X-ray films were ample in the European theater. Then, and for several weeks thereafter, there was a sudden and general shortage, which was found to result from the fact that

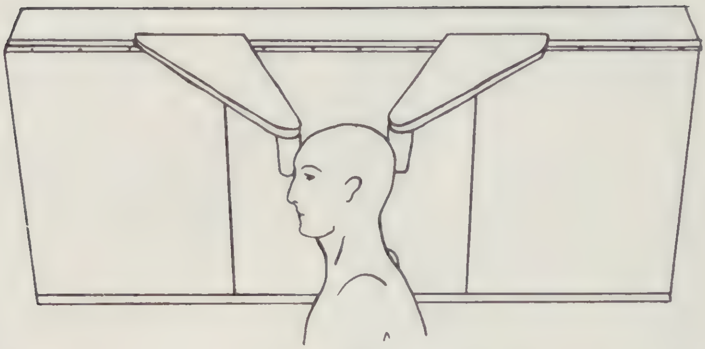

FIGURE 144.—Improvised removable, adjustable headrest for radiographs of lateral cervical spine (48th General Hospital).

British railway workers were not handling freight during the Christmas holidays. Otherwise, there was no serious shortage of films in the European theater throughout the war, even in forward areas, except for some temporary shortages of 10- by 12-inch films. Sizes 8 by 10 inches and 14 by 17 inches were never in short supply when requisitions for them were made promptly and correctly.

Films arrived regularly throughout the war and were distributed equitably to forward and rear hospitals. The supply from the United States was augmented by the purchase of 8- by 10-inch films (7,474 dozen) and 10- by 12-inch films from the Gevaert Film Factory in Belgium. After February 1944, no films were secured from British sources.

One reason for the ample supply of films was the campaign for conservation carried on by the Senior Consultant in Radiology and the regional consultants through personal contact and articles in the theater news bulletin (*3*).

Early in 1943, hospitals in the theater were using an average of two films for each examination. A year later, in 1,561,047 examinations reported on ETOUSA Form 320 (chiefly from rear area hospitals), only 2,230,537 films had been used, an average of 1.4 films. Part of the success in the reduction of the number of films used was due to the concerted efforts of all the consultants in radiology to have medical officers provide a sufficient history of each patient for the radiologist to be able to determine, on his first examination, what positions were required.

The consumption by size of the 2,230,537 films just mentioned was as follows: 8-inch, 515,750; 10-inch, 781,685; and 14-inch, 933,102.

It had been generally taken for granted that after hostilities began on the Continent, there would be a tremendous increase in the number of X-ray examinations each hospital would be required to make. The actual facts were quite different. During the quarter immediately preceding the inva-

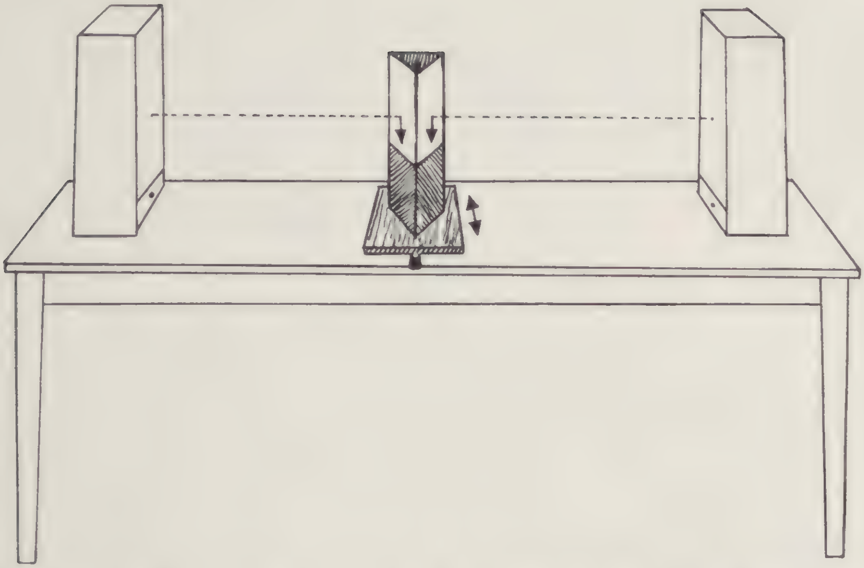

FIGURE 145.—Stereoscope constructed by attaching mirrors to sliding block between illuminators.

sion, 16 hospitals from which statistics are available made 35,527 examinations, an average of 2,220 per hospital. During the first quarter of 1945, the period beginning approximately 7 months after D-day, 113 general hospitals made a total of 334,948 examinations, an average of 2,964 each.

There were two reasons for the fact that the increase in X-ray examinations was not so great as expected:

1. After hostilities began, many hospitals experienced relatively long periods of moving and staging.

2. Radiographs made in forward area hospitals were transferred with the casualties in increasing numbers (p. 340), a practice which greatly reduced the number of reexaminations necessary.

In July 1945, the Finance and Supply Division of the Chief Surgeon's Office was requested by the Supply Division, Office of The Surgeon General, to send films to the Pacific. Colonel Allen was searching for local sources of supply when the hostilities in the Pacific Ocean Areas ended. When the fighting in Europe ceased, the supply on hand in ETOUSA consisted of about a thousand dozen 14- by 17-inch films.

Colonel Allen was so impressed by the cooperation of the various groups responsible for the production and delivery of X-ray films to the European theater that he wrote as follows in his annual report for 1945:

It is believed that the Supply Department, Surgeon General's Office, X-ray film producers in the United States, and the Supply Department of the ETO deserve extreme credit on the production, furnishing and delivering of unexposed X-ray film to all the

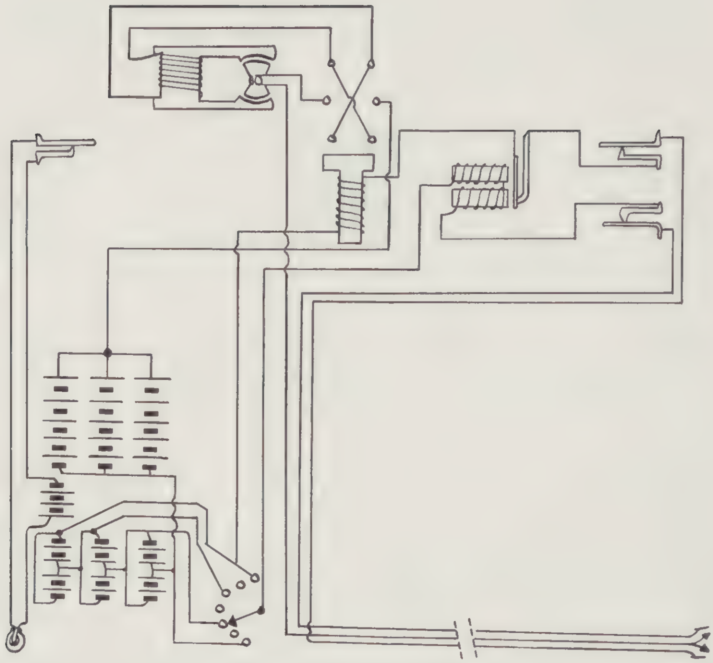

FIGURE 146.—Diagram of wiring for motor-driven Bucky diaphragm constructed by Maj. James B. Haworth, MC, at 46th General Hospital with use of Army field grid.

manifold units of the U.S. Army, ETO, throughout the front as well as the rear, with no instance since D-day known to the Senior Consultant in Radiology of inability to obtain film, except occasionally certain sizes.

Fogged Film

Many of the stainless steel inserts originally furnished from the United States were soldered on an inside corner, and the solder set up a chemical reaction which fogged the films. The difficulty could be corrected by the use of acid-resisting paint, which, however, could not always be procured. Some radiologists then resorted to the use of fingernail polish, which could be purchased in Army exchanges.

In these circumstances, the cause of the fogged films was easily recognized. During the summer and fall of 1944, however, there was so much fogging of films that a formal investigation was necessary. Two possible sources of the trouble were discovered:

1. Radioactive material, such as luminous paint, was occasionally present in the interstices of the cardboard cartons in which films were transported.

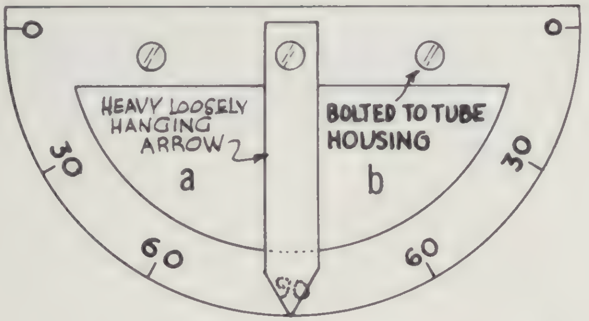

FIGURE 147.—Protractor for determining angle of tube. This device consisted of an inverted metal protractor with a heavy, loosely hanging arrow (a) indicating degree of deviation of tube from horizontal. Protractor was bolted to tube housing (b).

2. Stacking of cartons of film flat in warehouses, supply departments, and X-ray departments sometimes caused them to warp, open, and admit light.

About the time this investigation was concluded, Colonel Allen was summoned, in great haste and secrecy, by Lt. Col. (later Col.) William D. Fleming, MC, Chief, Gas Casualty Division, Office of the Chief Surgeon, and was asked if there was on hand any film that was fogged for unknown causes. The possible sources of fogging just stated were reported to Colonel Fleming, with the further information that no fogging had been discovered that could not be traced to them.

It was not until 29 May 1959, when Colonel Fleming and Colonel Allen met again, in Denver, that the incident was explained. Colonel Fleming's own words conjure up a vivid picture of Operation PEPPERMINT:

In March 1943, I reported for duty to Gen. Paul Hawley, Chief Surgeon, ETOUSA, and he created the Gas Casualty Division of the Office of the Chief Surgeon, designating me as chief. The duties of this division embraced the planning, supervision, and inspection of the training of all ETOUSA medical units in the care of casualties from chemical warfare agents. Defensive measures against chemical attack were left to the Chemical Warfare Service, but close liaison and splendid cooperation on all aspects of chemical warfare were maintained with that Service.

In April 1944, the Chief Surgeon, ETOUSA, was visited by an officer on a special and secret mission from the United States. Two years later (1946) I learned he came from the Manhattan Project, but at the time nothing whatever was divulged of that or even of the possibility of nuclear weapons. The greatest secrecy concerning the visit was maintained, and I believe the only medical personnel who were told of its purpose were the Chief Surgeon, his deputy or executive officer, and myself. A few corresponding CWS [Chemical Warfare Service] personnel were told and possibly because fogging of photographic material was an indication which was being surveyed, certain Signal Corps personnel may have been informed also. The code name for the matter was Operation Peppermint.

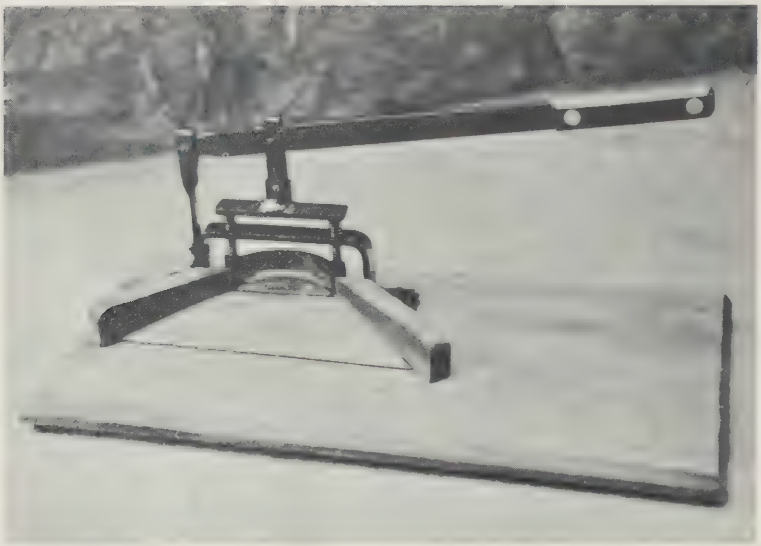

FIGURE 148.—Improvised film trimmer devised by Maj. Robert S. Sherman, MC, and T/3 Stanley S. Koupal, 43d General Hospital.

We were informed that there was reason to believe that the Germans had plans for the use of radioactive isotopes to be dispersed in a fine powder as a new form of chemical attack. One evidence of such radioactive material was unexplained fogging of photographic material including X-ray film used in medical units. To aid in confirming that any such fogging was due to radioactivity, I was supplied with a small, portable Geiger counter and a minute radioactive source for calibrating it.

An administrative memorandum based on the foregoing information was issued to all medical units using X-ray films, and directing, without mentioning any reasons, that any instance of unexplained X-ray film fogging be reported immediately to the Chief Surgeon, ETOUSA. An accompanying order was issued which authorized me to proceed at once to the point of origin of such report to investigate whether the presence of radioactivity might have been the cause of the fogging. I remember distinctly one such report from the 2d General Hospital, Oxford, England. A visit there and to the supply depot from which the films were shipped elicited no evidence of radio activity at either place.

On 14 November 1944, I was detached from the Office of the Chief Surgeon, ETOUSA, and proceeded by way of the United States through most of the Pacific Theater of Operations under orders to inspect the status of training of medical units in the care of gas casualties. As I remember I was ordered not to divulge any information regarding "Operation Peppermint" to the officer acting during my absence from the European theater. I returned in May 1945, and after three weeks in hospital in England reported for duty to the Chief Surgeon, ETOUSA in Paris late in May 1945. Soon after this I received orders to turn over the Geiger counter and radiation source mentioned to a designated officer, thus terminating my action in and my knowledge of "Operation Peppermint."

UTILIZATION AND EVALUATION OF EQUIPMENT

Principles of Utilization

The maintenance and protection of X-ray equipment always presented difficulties because of the frequent movement of forward hospitals, the cramped quarters and other unfavorable conditions encountered in forward areas, and the ease with which delicate equipment suffered damage. Careful preventive measures and skillful maintenance were required to keep the equipment constantly usable in the first echelon.

The scarcity of generators required that they be used most conservatively. Shortages of certain items of equipment required frequent improvisations. Tables of equipment provided too small a supply of some items, which had to be augmented, but provided too large a supply of others, which created problems of storage and transportation.

Certain general policies were set up with respect to X-ray equipment:

1. It was recognized that equipment was at the same time heavy and bulky as well as delicate and readily destructible.

2. Equipment was specifically integrated with radiologic diagnosis and treatment.

3. It would be allotted impartially, according to scientific and clinical necessities.

4. It must have expert and specialized maintenance.

All radiologists were instructed as follows (*1*):

> It behooves all ETOUSA radiologists to work unceasingly with their technicians to the end of producing radiographs of maximum diagnostic quality with the equipment available, even if photographic excellence cannot be added. In the meantime, representatives of the Chief Surgeon's Office will work just as hard and as unceasingly, to procure as many refinements on each machine, as many machines, and as powerful ones as can possibly be procured, without interfering with the overall program and the speed of production.

Radiologists were further urged to forego for the duration of the war their individual ideas concerning technique, while specialists who had practiced in a limited or narrow field of radiology were adjured to forego their individual—and sometimes bizarre—radiographic desires.

Utilization in Forward Areas

Between 30 July and 7 August 1944, the Senior Consultant in Radiology visited most of the hospitals and some clearing stations in Normandy. The work observed in them, and later in France, Belgium, and Germany, in mobile units and forward hospitals, was outstanding. This was evident in (1) the ability of their personnel to cope with sudden loads of patients long before their units were fully set up, and (2) their capacity for improvisation as difficult situations arose. They had to provide containers to hold water for washing films, drying facilities, tracks or flooring upon which

machines could be moved, power distribution, darkrooms for processing films and for fluoroscopy, waiting space for ambulatory patients, and protected space for litter patients. They had to do all of this while keeping their equipment within the limits of weight and size required for transportability, for changes in location were frequent and sudden.

Numerous improvisations were observed in the X-ray departments in forward hospitals. GI tanks were used for washing tanks, with inlets and drains in some of them. Films were hung in long rows by hooks on wires or string. Tents were placed close to electric generators, and hot air was forced into them by fans. These and other improvisations were mandatory, so that films could be interpreted promptly and dried sufficiently to be delivered to the surgeons in the operating rooms as they were needed.

The greatest single difficulty in the operation of forward X-ray departments was lack of adequate drying facilities, especially in cold, wet weather. Film driers were not on the official T/E of evacuation hospitals but, on Colonel Allen's advice, the Chief of Supply approved the allotment of one drier to each evacuation hospital and authorized the addition of this item to the T/E.

The following communication, received in 1958, from Dr. (formerly Major, MC) Henry G. Ford is testimony to the efficiency of the X-ray equipment used in the European theater in World War II.[4]

> I am sorry that I am unable to give you the number of casualties each outfit handled * * * I do remember that in the 305th Station Hospital X-ray worked five days and nights continuously.
>
> I still feel that this field equipment is satisfactory for these installations, and that the heavier equipment should be reserved for fixed installations. I always trained my personnel in field with the idea, as I stated to them, that we had to change our routine and adapt the X-ray machines to the casualty, rather than the casualty to the X-ray machine. In many instances the casualties were too severely wounded to be moved into various positions for the views, and we found that the above worked very nicely.
>
> We, as far as I know, were never too short of equipment and supplies to carry on an adequate X-ray service. I always found the depot and servicemen to be most anxious to help in any way possible.

CAPTURED ENEMY SUPPLIES

Equipment

Early in April 1945, when the U.S. Army was overrunning German installations, considerable enemy equipment was captured. A letter from

[4] The former Major Ford is well qualified to speak upon the efficiency of X-ray equipment, for on one occasion he handled 400 casualties in a single day. His first oversea duty was in the United Kingdom, in the X-Ray Department of the 305th Station Hospital, which had been enlarged to a 1,350-bed transit hospital to receive casualties from the Continent. He was then assigned to the 102d General Hospital, and later to the 166th General Hospital, in France. During his service in the 166th General Hospital, he functioned as regional consultant in radiology to the Normandy Base Section. In spite of his being overage in grade, he was most anxious for frontline service and he was perhaps the only radiologist in the European theater who welcomed an assignment to a tented hospital with dirt floors.

the Chief Surgeon's Office, ETOUSA, to the surgeons of the armies in combat instructed them to furnish the Senior Consultant in Radiology with copies of reports of all captured X-ray machines, so that he (Colonel Allen) could determine what use could be made of them (*4*). The reports were to include the name of the manufacturer, the apparent condition of the apparatus, and the name and location of the installation in which it had been captured. As a result, the following machines were reported: 31 Koch and Sterzel, 81 Siemens or Siemens Reiniger, 5 Philips, 14 Multoskop Sanitas, 11 Müller, 4 Veifa Werke, 2 Collinor, 2 Magneta Raumsicht, 1 Hoffman Bauer, and 1 Helidor. Forty-nine other machines were also reported without the names of the manufacturers. Many of these machines were neither modern nor shockproof and were discarded. Others could be used by U.S. hospitals, though parts of many were missing.

Considerable X-ray material was also found in a captured supply depot at Rheims. It was inspected and sorted by Colonel Allen, and the items which could be used were transferred to X-ray Service Depot M–407 at Paris.

When enemy equipment was captured incomplete, considerable ingenuity was required to replace the missing parts and make it useful again. Often this had to be accomplished by adaptation of parts from U.S. Army machines. The effort was often well worthwhile.

Radium

In April 1945, during the siege of Aachen, a large quantity of radium was discovered and was turned over to the Chief of the Finance and Supply Division, Office of the Chief Surgeon. When the Senior Consultant in Radiology was invited to view it, he found that it was stored in a room in which a number of persons were at work, and tests with dental films revealed that some radiation was escaping from the lead box in which it was contained. Colonel Allen at once recommended that the radium be placed either underground or on the roof of the building, with a considerable amount of lead under it, as protection to personnel. The recommendation was promptly implemented.

Additional problems connected with this radium included:

1. Its identification and return to its owners. The price of radium was much higher in 1945 than it is today (1965), and the amounts recaptured were very valuable.

2. Military legal protection for those responsible for the recaptured radioactive material.

Colonel Allen recommended that the disposition of the radium and other matters connected with it be handled by a board, and one was accordingly appointed by the Chief of the Finance and Supply Division, Office of the Chief Surgeon. Colonel Allen further suggested that a fair allotment might be made by calibrating the radium exactly and then surveying (1)

the requests for it sent in by the French, from whom it had been confiscated by the Germans, and (2) the records of hospitals indicating the exact amounts each had originally owned.

Measurement of the radium was accomplished at the Pierre Curie Institute in Paris, where the Senior Consultant in Radiology had an extremely interesting visit with Mme. Irène Joliot-Curie, the daughter of Mme. Marie Curie, and her husband, Dr. Frederic Joliot-Curie. The two scientists were most gracious and agreed to calibrate, by ionization methods, any radium brought to them. Their assistance was most useful.

A hospital in Aachen presented a claim for the exact amount of radium that was in the first batch recaptured, and the board set up by the Chief of the Supply Division unanimously agreed to return the radium to that claimant.

The next recaptured radium was reported from the Third U.S. Army front in lower Bavaria. It presented considerably more of a problem, as it had been scattered, in the wreck of a truck, over several square miles of ground surface. The Senior Consultant in Radiology designated Maj. (later Lt. Col.) Frank Huber, MC, radiologist at the 12th Evacuation Hospital, to investigate the situation, monitor the recovery of the radium, and offer advice as to its handling.

When Major Huber arrived on the scene, a highly dangerous situation was evident: In the ditch, by the side of the road, was the overturned, burned wreck of the truck. A pile of charred debris, aggregating about 2 cubic yards, was spread over a distance of about 10 feet, on the shoulder of the road, and rummaging through it were several privates looking for souvenirs; an armed guard stood close by a neatly stacked pile of lead slabs about a foot high.

All personnel were immediately ordered away, as the presence of high intensity radioactivity was ascertained by means of a Victoreen r-meter and a Hammer dosimeter operated by a civilian technician from the University of Munich. This apparatus was not available in the U.S. Army. The radium, about 3 gm. of which was involved, had presumably been partly in solution, and spillage accounted for the wide dispersal of radioactivity.

The truck had been part of a convoy from Budapest which was fleeing the Russians and had been strafed by the Americans. In it were the Mayor of Budapest and the superintendent of one of the Budapest hospitals. Both wished to obtain possession of the radium and have it reprocessed at a refining plant.

Suitable orders were left for protection of personnel and handling of radioactive material if transportation could be obtained. Some of the recovered radium was returned to the Senior Consultant in Radiology, who disposed of it by the plans described earlier. What happened to the ground polluted by radioactive material is not known.

In July 1945, just before Colonel Allen returned to the Zone of Interior,

a rumored German hoard of 20 gm. of radium was reported to him. The rumor—it was no more—was investigated by a radiologist appointed by the Chief Surgeon, ETOUSA, and resulted in the publication of Circular Letter No. 72, dated 8 October 1945, dealing with the handling of radium (*5*).

X-RAY SERVICE DEPOT

Establishment

The problem of servicing X-ray equipment was increased many times over by the multiple models of X-ray machines used in ETOUSA. Before Colonel Allen arrived in the theater, steps to service this equipment had already been taken by the Acting Senior Consultant in Radiology, Lt. Col. Robert P. Ball, MC; the Senior Consultant in Surgery, Col. (later Brig. Gen.) Elliott C. Cutler, MC; and the Chief and the Assistant Chief of the Finance and Supply Division, Office of the Chief Surgeon.

The service depot established as the result of these efforts, designated as X-ray Service Depot M–400, consisted of a building of 17,800 square feet of covered space at Reading, England. It was opened on 4 February 1943. At this time, it was believed to be the only service depot in the U.S. Army exclusively devoted to X-ray maintenance.

The establishment of this depot was the first step in coping not only with the maintenance of X-ray equipment but with another serious problem, the repair of equipment damaged in transit (p. 367). Installation of X-ray equipment was another function of this depot. Upon the advice of Colonel Ball, the Chief of the Finance and Supply Division, Office of the Theater Chief Surgeon, instituted the policy that all equipment arriving in the United Kingdom from overseas, and all equipment purchased from the British, must pass through depot M–400, which was to function only as a service depot, not as an issuing agency. This policy was discontinued in the summer of 1944 so far as equipment intended for forward area hospitals was concerned, since improved packing had greatly reduced the breakage of field equipment in transit.

Before adequate personnel were secured for depot M–400, Colonel Allen had endeavored to organize an X-ray equipment service by utilizing civilian X-ray companies in England. Although considerable service was obtained, it was variable in quality and tardy in execution, because of the exigencies of war and the pressure on these civilian companies.

Personnel

The lack of both tools and personnel worked great hardship in the early days following the activation of the M–400 depot. The Finance and Supply Division eventually produced the tools and, by the combined efforts of that

division and the Personnel Division, Office of the Chief Surgeon, and of the Senior Consultant in Radiology, expert personnel was slowly accumulated.

The first three experts located were found serving as X-ray technicians, one at the 2d General Hospital (1st Lt. William A. Wyckoff), and two at the 52d General Hospital (Chief Warrant Officer Todd and WO (jg.) George E. Dryfoos). Lieutenant Wyckoff became commanding officer of the depot.

In a report made on 29 April 1943, the Senior Consultant in Radiology estimated that between 12 and 18 men would eventually be necessary at the depot. His estimate proved too low. By May 1945, depot M–400 and two others, depots M–407 and M–409 on the Continent, had approximately 40 repairmen on duty. They had been located, like the first three, by the radiologic consultants and the personnel of the Finance and Supply Division who, by intensive effort, found them in various other assignments. More often than not, when their names were referred to the Personnel Division, considerable difficulty was encountered in bringing about their reassignment.

Continental Branches

Depots M–400, M–407, and M–409 eventually became both service and salvage depots for all types of medical equipment. Commanding officers of these depots, with the consent of the Chief of the Finance and Supply Division, Office of the Chief Surgeon, inaugurated a plan whereby X-ray service trucks made periodic visits to hospital X-ray departments, carrying with them spare parts that could be exchanged through a shuttle system. If, for instance, an item such as a generator needed major repairs, it was replaced on the spot by a spare from the truck, and the original generator was repaired when the truck returned to the depot. This service was especially valuable in forward area hospitals on the Continent. It began with anesthetic and ophthalmologic equipment and went on to repair and maintain general hospital equipment.

Spare Parts

In April 1944, after a series of meetings, a plan was devised for procuring and pooling the U.S. supply of spare parts for British machines and tables in service depot M–400 with the supply in the X-ray stores of the British Army. The idea was that by pooling these supplies and by using a shuttle system to replace broken equipment, a much smaller supply of spare parts and equipment would be necessary for each army. The program, however, was slow in developing and never operated formally, chiefly because X-ray manufacturers in the United States and Great Britain were extremely reluctant to furnish spare parts as such. They preferred cannibalization of fabricated and calibrated X-ray machines to secure these parts, although this plan was deprecated by the X-ray services in both British and United States Armies as wasteful of manpower and shipping space.

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4. Letter, Chief Surgeon, ETOUSA, to surgeons of all U.S. Armies, 4 Apr. 1945, subject: Captured Stationary X-Ray Machines.

5. Circular Letter No. 72, Office of the Chief Surgeon, Headquarters, ETOUSA, 8 Oct. 1945, subject: Transportation and Storage of Radium.

CHAPTER XIII

Auxiliary Mobile X-Ray Units

Kenneth D. A. Allen, M.D.

INCEPTION AND DEVELOPMENT

By June 1943, the Office of the Chief Surgeon, ETOUSA (European Theater of Operations, U.S. Army), had received enough information concerning the augmentation of surgical service that had been required in other theaters to justify an investigation of the possible need for parallel radiologic augmentation in the European theater. Interviews with medical officers returning from service in forward areas in North Africa, notably Maj. (later Lt. Col.) Noah Barysh, MC, stimulated the investigation. Although Major Barysh was not a radiologist, he provided much valuable information on radiologic work in forward hospitals, emphasizing, particularly, the inequality of the workload: One hospital might be overburdened, while another, nearby, might have very little to do. He also emphasized the value of mobile surgical units (auxiliary surgical group teams) in field and evacuation hospitals carrying heavy surgical loads.

The data thus secured made it clear that augmentation of radiologic service would be necessary not only in field and evacuation hospitals in forward units but also in certain other medical units along the front, such as reinforced clearing stations and units improvised from medical gas casualty treatment battalions, in which, up to this time, X-ray assistance had only occasionally been needed. Convincing evidence of these necessities was also obtained through personal observation by Colonel Allen during his visit to North Africa and Italy, which lasted from 16 September to 16 October 1943 (*1*). It was quite clear that, if existing X-ray departments were not to become bottlenecks in the treatment and evacuation of the wounded, mobile X-ray units must be provided soon after the invasion of the Continent.

Construction of Prototype Mobile Unit

In anticipation of the need for mobile X-ray units, Lt. Col. Kenneth D. A. Allen, MC, had arranged, before his departure for the North African theater, for the assembly of an experimental unit of this kind. It completed the last portion of a thousand-mile supervised road test shortly after his return to the European theater.

The prototype mobile unit was constructed of materials procured either by loan or by permanent transfer from other agencies. The truck itself was loaned by the Ordnance Division. All construction work and installation were accomplished by the maintenance personnel of depot M–400 (p. 401), in addition to their regular arduous duties.

In general, this prototype met the requirements which Colonel Allen, in his visit to the North African theater, had concluded were necessary. They were as follows:

1. The unit should be rugged.

2. It should be equipped with general issue items and should be without luxuries.

3. It should be capable of being set up and operational within an hour of its arrival in any area. This requirement included pitching and preparing the radiographic room tent and the blackout entrance tent and making ready darkroom facilities, such as lighting; ventilation; heating or cooling of processing solutions; preparing wash water; and accomplishing a total blackout.

Colonel Allen and his temporary assistant, Capt. (later Maj.) Charles D. Rancourt, MC, tested many arrangements of equipment and various types of equipment before the final construction plans were completed and the table of equipment established.

Final Model

The mobile X-ray unit (fig. 149) consisted of a 2½-ton 4DT (dual tires) cargo LWB (long-wheelbase) truck, commonly known as a 6-by-6 truck. The first three trucks produced had a full-length body fixed upon a short-wheelbase chassis. The result was an 84-inch overhang behind the rear axle, which interfered with crossing ditches and with passage over rough ground. These units were disapproved, and the completely installed bodies were transferred to long-wheelbase chassis.

The three generators were provided with rubber cushioning to prevent vibration (fig. 150). A rack carried cans for the processing and wash water.

When the unit was set up (figs. 151–154) the darkroom was in the truck proper, with facilities for lighting, refrigeration, and the drying of films. The blackout entrance tent served as a waiting room.

AUTHORIZATION AND PROCUREMENT

By 26 October 1943, all the fundamental adjustments of the experimental unit had been completed and a table of equipment had been printed. Also, an effort to secure official approval had been begun: On 29 October 1943, the Office of the Chief Surgeon, ETOUSA, had forwarded to The Adjutant

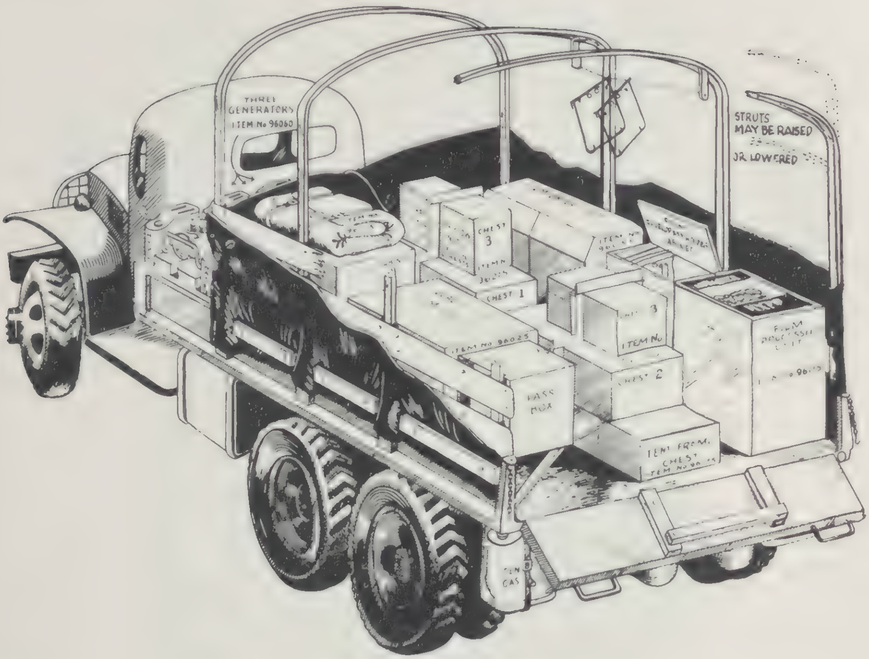

FIGURE 149.—Auxiliary mobile X-ray unit loaded for move to new location.

General of the Army, for the attention of the Operations Division, War Department General Staff, Project No. 2 "SURG." Requisitions A. 287.

On 8 December 1943, the project received the required approval in Washington, and supply action was initiated for the equipment of the six units proposed.

Through the efforts of Col. Walter L. Perry, MC, then Chief, Finance and Supply Division, Office of the Chief Surgeon, ETOUSA, equipment for these units was gradually accumulated. The Chief Ordnance Officer, ETOUSA, had agreed to install it, but each step in the production of the units, including approval for equipment and installation, was accomplished only at the personal solicitation of the Senior Consultant in Radiology.

PERSONNEL AND TRAINING

On November 1943, at the weekly meeting of the theater consultants, a decision was made to request Maj. Gen. Paul R. Hawley, Chief Surgeon, ETOUSA, to authorize six mobile X-ray units, each to be staffed by one radiologic officer and three technicians. Three of these teams would be assigned to the 1st Auxiliary Surgical Group, which was expected to be assigned to the First U.S. Army, and the other three teams to the 3d Auxiliary Surgical Group, which was expected to be assigned to the Third U.S.

FIGURE 150.—Generators of auxiliary mobile X-ray unit, equipped with rubber cushioning to prevent vibration. These generators, when thus protected, gave no more trouble than if they had been stationary. An extension of the tarpaulin over the back of the truck, which excluded carbon monoxide from the darkroom, protected them during rain.

Army. The exact assignment of the radiologic officers had not yet been determined, but two plans were under consideration. The first was to place them in command of designated mobile X-ray units. The second was to make them members of the auxiliary surgical groups and use them to augment forward area radiologic personnel as the needs arose.

Efforts were begun at once to obtain the necessary personnel for these six units (MOS 3306 radiologists and MOS 264 [1] technicians), as well as for six more units for other armies. Their procurement was no simple matter. Six officers were needed at once, with the rank of captain, and no table of organization then existed for them. Finally, however, the required numbers of radiologists and technicians were obtained by exchanges and transfers from various hospitals, the officers' pool at Litchfield, and the Air Corps.

[1] Army Regulations 615–26, dated 15 September 1942, listed X-ray technicians under this code, which in 1950 was changed to MOS 3264.

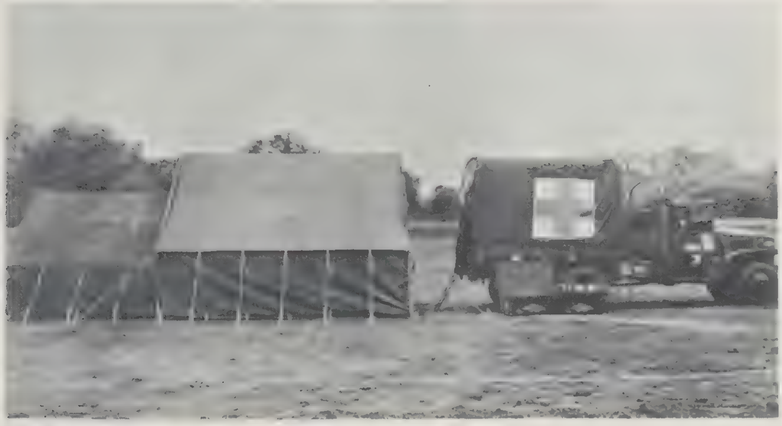

FIGURE 151.—Auxiliary mobile X-ray unit set up in field for daylight use. At night, tent and truck were connected by a blackout tarpaulin.

The training of the technicians was begun with the experimental model under the direction of Captain Rancourt, who was placed on temporary duty with the 3d Auxiliary Surgical Group for this purpose. In addition to their training in radiography, the technicians were instructed in truck driving and maintenance, generator maintenance, second echelon (ordnance) repair, tent pitching, truck waterproofing, and extensive improvisation.

On 22 March 1944, in response to the evident need for a manual for guidance of officers and men of mobile units, the Senior Consultant in Radiology, ETOUSA, undertook this project. When the manual was completed, in April 1944, it was distributed not only to mobile X-ray units but also to all medical units of the First U.S. Army, and, later, of the Third U.S. Army, to make them aware of the functions and availability of this new medical organization.

After instructional visits by the Senior Consultant in Radiology, the First U.S. Army requested three mobile X-ray units, which were duly assigned to it and delivered late in February 1944. Meantime, one of these units had been thoroughly inspected earlier in February, at Cheltenham, Gloucestershire, by the theater chief surgeon and his staff. General Hawley's hearty approval and acceptance of the unit ended Colonel Allen's natural suspense. He (Colonel Allen) then believed that such a unit had never before been used, or even conceived of; it was not until after the war had ended that he learned that similar mobile units had been employed in World War I (p. 49).

In May 1944, shortly before D-day, three mobile units were also requested by the Third U.S. Army. These units had begun vigorous training several months earlier and were ready for immediate delivery.

An account of the organization and function of these mobile units

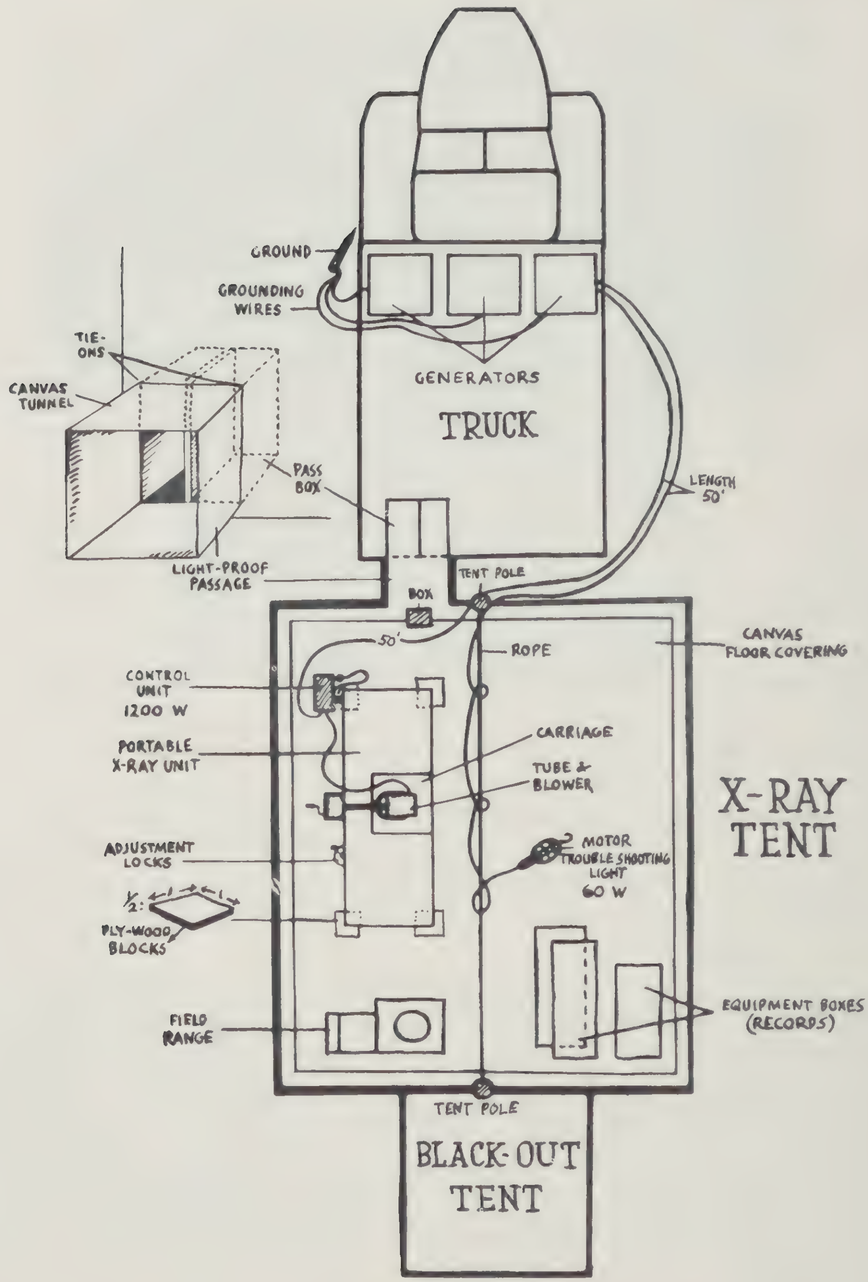

FIGURE 152.—Diagram of mobile X-ray unit set up in field.

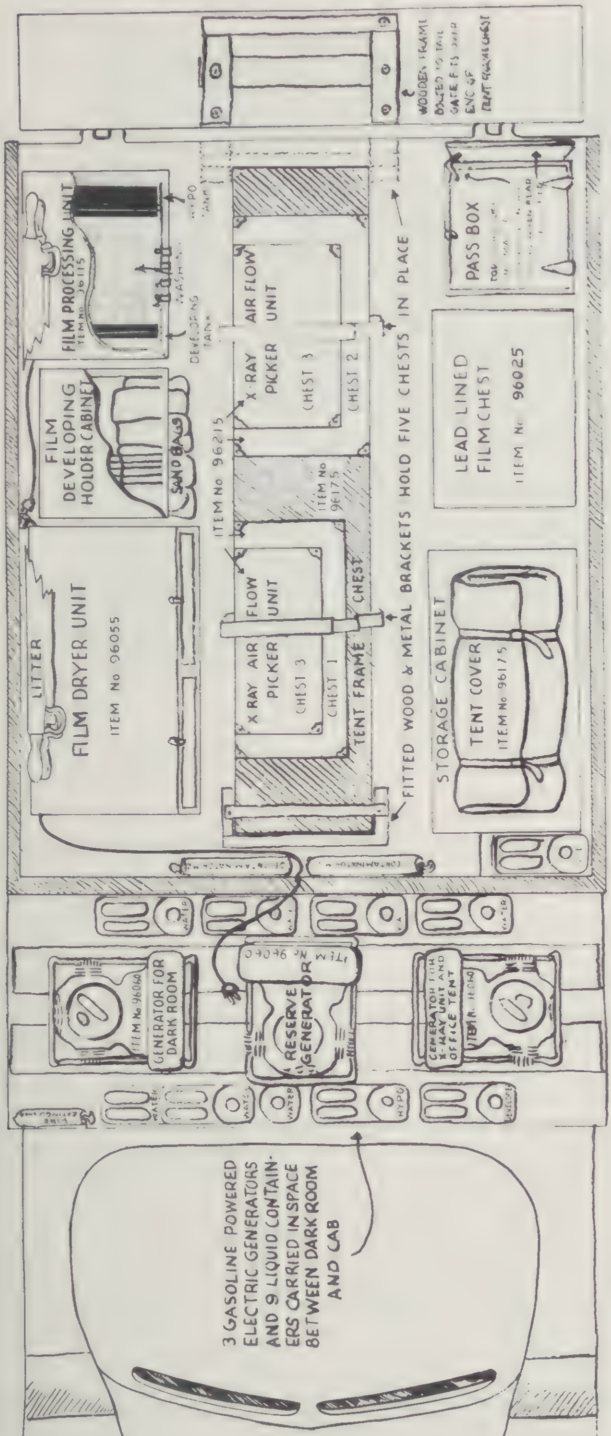

FIGURE 153.—Floor plan of mobile X-ray unit.

FIGURE 154.—View of interior auxiliary mobile X-ray unit with radiographic room in foreground and darkroom in rear of truck in background.

appeared in the *Journal of the American Medical Association* for 8 July 1944 (*2*).

On 13 June 1944, a mobile X-ray unit was first used in the treatment of casualties by a team from the 1st Auxiliary Surgical Group, while the team was still assigned to the Services of Supply in the United Kingdom Base. Colonel Allen described the episode in his official diary as follows:

At 1500 hours, 13 June 1944, the Senior Consultant in Radiology was called to furnish an Auxiliary Unit for a near shore platoon of the 50th Field Hospital, because it was overwhelmed by radiographic requests beyond the capacity of its personnel and equipment. One mobile unit from the 1st Auxiliary Surgical Group proceeded to Weymouth from Swanage, England, arrived at 1900 hours, set up completely, and had first radiographs ready at 2000 hours. By the next morning the unit had made fifty examinations.

This operation was a prelude to operations on the Continent. The first three mobile X-ray units arrived in France on 28 June, 22 days after D-day, with the 3d Auxiliary Surgical Group, First U.S. Army. Typical histories of Unit No. 1, commanded by Capt. William G. O'Donnell, MC, and Unit No. 2, commanded by Capt. (later Lt. Col.) Albert J. Bauer, MC (fig. 155), were included in the final report of the Senior Consultant in Radiology.

Additional mobile X-ray units were requested during the summer and fall of 1944, as their potentialities were appreciated. They were supplied,

FIGURE 155.—Personnel of Team No. 2, 3d Auxiliary Surgical Group, left to right: T/5 Kenneth Evans, T/4 Nicholas D'Agostino, T/5 Abraham Novick, and Capt. Albert J. Bauer, MC, all veterans of 1944 summer campaign in France.

the equipment and its installation with increasing facility but personnel with increasing difficulty.

By the end of 1944, all 12 of the auxiliary mobile X-ray units which were to serve in the European theater during the war had been established. Their status at this time was described in the 1944 annual report of the Senior Consultant in Radiology substantially as follows:

The present composition of Auxiliary Mobile X-ray teams consists of one Major or Captain, radiologist (3306); one X-ray technician (264), third grade; two X-ray technicians (264), fourth grade (because of the quality of technicians required). They must be not only expert radiographers but truck drivers and maintainers and also familiar with gas-electric generators.

The morale of a team was usually best when the radiologist was not over thirty-five years of age, one of the best Class D 3306 officers available, and when the officer-radiologist's rank and the technicians' grade was the same as that of other "professional services."

Twelve of these teams are presently formulated, three with First Army, four with Third Army, two with Ninth Army (one loaned to Third Army), one with Seventh Army, and two awaiting assignment. At present the teams are functioning well under Auxiliary Surgical Groups maneuvered by Operations Section of the Surgeon's Office of Army Headquarters. These teams were activated by direction of Chief of Troop Movements and Training, the Operations Division of the Chief Surgeon's Office, effective 22 May 1944, by the following communication: "* * * 3. Until such time as definite T/O's

do come out whereby X-ray teams are provided, it is up to the Auxiliary Surgical Groups to improvise X-ray teams from their miscellaneous teams which they are presently authorized to have under their present T/O's. s/A. Vickoren, Colonel, Medical Corps."

In spite of periodic requests, no official approval for the personnel of X-ray teams was received until 18 June 1945. On that date, the War Department formally approved the teams and issued a table of organization and equipment for them. During the interim, it was necessary for each auxiliary surgical group to improvise X-ray teams that it was authorized to have under existing tables of organization.[2]

FUNCTIONS

Original Concept

The functions of auxiliary mobile X-ray units, each with a radiologic officer in command, were outlined by Colonel Allen in his annual report for 1943 substantially as follows:

1. To augment any evacuation or field hospital X-ray department during times of stress with personnel, radiography, or both.
2. To furnish radiologic service in occasional situations in which surgery might be required and postoperative beds had been obtained but no field hospital unit was yet available.
3. To serve temporarily at dispensaries of bivouacking divisions recently withdrawn from the front when these units were at a considerable distance from the nearest hospital, and to render assistance in similar situations.

Expanded Functions

While, in general, the functions of the mobile X-ray units during the fighting on the Continent were those originally envisaged by Colonel Allen, these units proved more useful than even he had anticipated. In his annual report, dated 1 July 1945, he described their expanded functions substantially as follows:

1. To amplify evacuation hospital X-ray departments. During the summer phase, when most of these hospitals were in tents, the auxiliary units set up as separate X-ray departments, complete within themselves. Records of patients, however, were handled through the day book of the hospital department; only enough data were kept in the mobile unit to permit the compiling of necessary statistics. During the cold winter months, when most evacuation hospitals moved into buildings, the personnel of the mobile unit often alternated with that of the evacuation hospital on day and night shifts. Usually, only the cassettes and hangers of the mobile unit equipment were used, but in some locations, it was possible to back the unit truck up to the window of the hospital X-ray

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[2] In the table of organization and equipment issued on 18 June 1945, only two technicians were allotted to each unit. In the European theater, it was found essential that each auxiliary mobile X-ray unit have three technicians, and that at least two of them be capable of driving the unit truck. A smaller allotment of technicians curtailed the efficiency of the teams in the performance of their principal functions and also reduced their value as a potential pool.

department and utilize the darkroom portion of the unit equipment, thus providing additional facilities for processing films.

2. To augment field hospitals. This utilization of the units was less common, but was sometimes very necessary. One unit, for instance, worked a full month with the 50th Field Hospital (p. 428).

3. To serve as the X-ray department of an improvised evacuation hospital staffed by a medical gas casualty treatment battalion. This plan was used in the First U.S. Army.

4. To furnish auxiliary teams of radiologists and technicians. The three radiologists and nine X-ray technicians at the disposal of Army headquarters formed a valuable pool from which assistance could be drawn temporarily to stem attrition or cover temporary disability of radiologic personnel. It was the general opinion that this function alone would have justified the organization of the mobile X-ray units, even without their equipment. Only occasionally, however, during the winter, was the equipment out of use for any extended period; the three generators, in particular, were practically always in use.

5. To man mobile mass radiography units, which must be available at the base in any long-active theater of war. One such team on the Continent, before being sent into an Army area, performed 5,240 examinations on officer candidates. The films were processed and interpreted at the rate of 184 per day. Little previous training was needed for this function.

6. To serve as the X-ray departments of captured German hospitals. Between 15 May and 10 June 1945, Team No. 62 of the 3d Auxiliary Surgical Group, Ninth U.S. Army, served in this capacity at the German Hoexter Military Hospital for tuberculous Russian prisoners of war, while Team No. 61 operated in the same manner at the Nordhausen Camp Hospital for Displaced Allied Personnel.

7. To assist at sick calls of bivouacking divisions, thus eliminating the need for transporting patients to hospitals simply to secure X-ray examinations. It had been expected that this would be a constant team function, but no reports of such use of the teams were made until after V–E Day. If enough units had been available, this service would probably have been useful during hostilities.

EVALUATION OF WORK OF MOBILE UNITS

A compilation of reports submitted to the Senior Consultant in Radiology on 1 May 1945 from 11 of the 12 mobile units operating in the European theater revealed that, although some had been in action only a short time, these units had handled a total of 37,231 patients, made 52,517 examinations, and processed 81,335 radiographs. Table 10 gives the breakdown of these figures by teams and also gives the length of service, the types of installations, and other details concerning the service of these units. A single unit often disposed of as many as 130 patients in a day.

In evaluating the work of the auxiliary mobile units, it should be borne in mind that most of the patients handled in them represented the overflow of the X-ray departments of the installations augmented by them. The practical need for them is evident in the fact that without their aid this overflow of patients would have created serious bottlenecks in both surgery and evacuation.

The opinion of others concerning the work of the units was highly favorable, as evidenced by comments of medical officers who had worked with them and of others who had observed them. On 31 July 1944, Capt. Joseph

TABLE 10.—*Statistical summary of work of mobile X-ray units in European theater*

Team	Months of service to 1 May 1945	Types of units served	Average time with each unit (months)	Number of days of operation	Number of patients [1]	Number of examinations [2]	Number of radiographs [3]
A	7	6 evacuation hospitals.	1¼	190	5,432	8,621	13,764
B	10	4 evacuation hospitals, 1 gas casualty treatment battallion.[4]	2	252	3,158	3,910	5,093
C	[5] 8½	4 evacuation hospitals, 1 gas casualty treatment battalion.	1½	161	1,427	3,316	[6] 3,316
D	10	10 evacuation hospitals.	1	189	4,368	([7])	11,210
E	11	3 evacuation hospitals, 1 field hospital.	2	203	4,489	7,707	11,662
F	9	7 evacuation hospitals.	1	203	4,374	9,427	6,228
G	2	1 field hospital, 1 medical collecting company.	1	34	5,240	5,240	5,300
H	6	6 evacuation hospitals.	1	([7])	2,560	4,996	7,397
I	4	1 evacuation hospital.	4	88	([7])	2,636	([7])
J	2	1 evacuation hospital.	2	33	522	677	1,687
K	6	6 evacuation hospitals.	1	123	4,097	4,377	12,339
L	3	1 evacuation hospital.	⅝	74	1,564	1,610	3,309

[1] Total number treated: 37,231.

[2] Total number of examinations made: 52,517.

[3] Total number of radiographs processed: 81,335.

[4] Acted as the entire X-ray department when medical gas casualty treatment battalion was converted into a hospital.

[5] Two months not recorded.

[6] Probably in error.

[7] No record received.

V. Robbins, MC, at the request of the commanding officer of the 3d Auxiliary Surgical Group, described the work of the unit attached to that group and mentioned the favorable reception of their aid by commanding officers, inspectors, surgeons, and other medical officers. It was Captain Robbins' recommendation that they be activated officially and attached to the various armies.

On 4 August 1944, Lt. Col. (later Col.) Joseph Augustus Crisler, Jr., MC, commanding officer of the 3d Auxiliary Surgical Group, after observing the three units which had arrived, respectively, on 29 June, 5 July, and 12 July 1944, stated that these units had been of definite value in augmenting X-ray facilities in evacuation hospitals, assisting overtaxed departments, and preventing bottlenecks. He recommended that each army be provided with an adequate table of organization for officers and enlisted men for these units.

On the whole, considering the peculiar character and function of these units, the operations officers of the armies on the Continent utilized them very well. The principal criticism of their utilization concerned the tendency to retain them too long in single locations. The average time the teams served with individual units was 1.6 months (table 10).

In retrospect, it seems that, in the future, a complete auxiliary mobile unit should be attached to an evacuation hospital each time it moves, so that radiographic functioning can begin within an hour of arrival at the new location. The organic X-ray department of the hospital could then set up more slowly and more carefully, without falling behind and creating a bottleneck in the surgical section. The rationale behind this suggestion is that most bottlenecks in the X-ray departments of evacuation hospitals in World War II occurred during the first few days they were functioning at new sites.

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2. Medicine and the War: Mobile X-Ray Units for Invasion. J.A.M.A. 125:711, 8 July 1944.

CHAPTER XIV

Radiology in Forward Areas

Kenneth D. A. Allen, M.D.

INITIAL PLANNING

As planning for the invasion of the Continent proceeded in ETOUSA (European Theater of Operations, U.S. Army), it became clear that radiologic service in forward areas would differ materially from radiologic service in rear areas. It also became evident that some means must be devised to augment this service at points of military stress, to parallel surgical augmentation at these points (p. 347). A study of operations in NATOUSA (North African Theater of Operations, U.S. Army) suggested that one practical and effective solution of the problem would be the use of teams from auxiliary surgical groups, according to the plans used successfully in that theater. Another plan involved the use of mobile X-ray units (p. 405). Both plans seemed particularly desirable and feasible because it was expected that the campaign on the Continent would be fast moving and that hospital facilities must be highly mobile if the proper service for wounded casualties were to be provided.

The Senior Consultant in Radiology, ETOUSA, was ordered to the North African theater on 16 September 1943, to make a firsthand study of the radiologic practices in use there (*1*). The experience in North Africa, Sicily, and Italy pointed clearly to the need for:

1. Mobile X-ray teams.
2. Augmentation of certain items of X-ray equipment.
3. An accurate estimate of film needs.
4. Reinforcement of X-ray personnel in forward area hospitals.

The following points, incorporated by Lt. Col. Kenneth D. A. Allen, MC, in the official report of this visit, were stressed by Col. (later Brig. Gen.) Joseph I. Martin, MC, Surgeon, Fifth U.S. Army, and other personnel shortly after the invasion of Italy: [1]

[1] Up to the time when the Senior Consultant in Radiology, ETOUSA, arrived at the Office of the Surgeon, Headquarters, NATOUSA, in Algiers, no consultant in any of the medical specialties had been permitted to proceed to Italy. The theater surgeon, Brig. Gen. Frederick A. Blesse, sent a "radio" to Colonel Martin requesting permission for Colonel Allen to visit X-ray installations at the front. As his own requests for similar permission for theater consultants had been refused, General Blesse thought this request would also be refused. To his surprise, and to the consternation of his consultants, the permission was granted. The mystery was cleared when it was learned from Colonel Martin that he had been having X-ray bottlenecks and, if Colonel Allen would bring him an analysis of the X-ray situation at the front, he would be glad to furnish him with a jeep and a driver. These arrangements were made, and Headquarters, Fifth U.S. Army, made every endeavor to see to it that Colonel Allen's tour was profitable.

1. No matter how carefully medical service is planned for an assault campaign, and no matter how excellent the planned procedures may be, one must be ever ready to change them to meet the circumstances which may arise during an assault.

2. A 15-percent loss of equipment must be expected during landing operations.

3. Plans for the location of medical units in an assault often require complete and abrupt changes. In Sicily and Italy, for instance, corps medical battalion clearing companies were used to reinforce divisional clearing stations and were followed by auxiliary surgical group teams pending the arrival of field hospital platoons. In these circumstances, surgery had to be performed without accompanying X-ray service, which could, however, have been supplied by mobile X-ray units.

4. Adequate X-ray service should be rendered wherever surgery is feasible. The official tables of organization and equipment of X-ray departments do not provide a radiologic capacity commensurate with the surgical capacities of a unit, especially when forward units are augmented by auxiliary surgical group teams.

5. Central power from the hospital plant, carried to the department by a #4 or larger wire, is preferable to the use of 2.5-kw. X-ray gas electric generators.

6. The need for radiographic standardization should always be stressed.

During Colonel Allen's visit in Italy, a great deal of valuable information was gained concerning shortages likely to occur in X-ray equipment during active hostilities. Much of the planning for X-ray equipment in the European theater was based on the information gathered during this visit. Valuable information was also gained concerning the transportation of X-ray equipment.

After his return from this trip, the Senior Consultant in Radiology held many conferences with the chiefs of the Finance and Supply and the Personnel Divisions, Office of the Chief Surgeon, ETOUSA, during the fall and winter of 1943–44. The inadequacies in equipment that might be expected after the invasion of the Continent were stressed, and the Finance and Supply Division inaugurated action to overcome them. The chief of the Personnel Division also took steps to supply additional radiologists and technicians for evacuation hospitals and for the auxiliary mobile units then being organized.

STANDING OPERATING PROCEDURE FOR THE INVASION

On 30 March 1944, each senior consultant in the Professional Services Division, Office of the Chief Surgeon, ETOUSA, was called upon by Maj. Gen. Paul R. Hawley to prepare an SOP (standing operating procedure) for his specialty during the invasion, which would be an operation typical of ground warfare but preceded by cross-water transportation.

The request to the Senior Consultant in Radiology, ETOUSA, from Lt. Col. (later Col.) Robert M. Zollinger, MC, read as follows:

1. Professional Services Division is responsible for preparing an S.O.P. for the management of casualties. This should include the general policy, starting at the "far shore," including LST's in formation for triaging officers at the "hards,"[2] as well as the transit hospitals on the "near shore."

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[2] A portion of a beach especially prepared with a hard surface extending into the water, employed for the purpose of loading or unloading direct into or from landing ships or landing craft.

2. Submit a detailed plan for each area, including the placement of surgical teams.

3. The policies of professional care will be governed by Manual of Therapy, ETO.

4. The submitted plans will be correlated at the Saturday morning meeting on April 1st. It is planned that Col. Clinton S. Lyter [MC] of the 1st Auxiliary Surgical Group will attend this meeting, to supply information regarding the number of his teams, as well as their equipment.

On 2 April 1944, Colonel Allen replied to this communication as follows:

1. X-ray examinations are advised whenever a medical installation has surgical facilities, and at least 100 beds, in other words, whenever X-ray examination will affect the treatment of relatively large numbers.

2. "*Near shore.*" The unit of a field hospital at the "hard," the regular T/O & E of which is one X-ray technician and X-ray equipment, will probably not need a full time radiologist, if only local casualties are handled, but the unit X-ray department should be under the supervision of the radiologist of the field hospital. This radiologist should visit the unit or delegate supervision through the C.O. of the field hospital to another medical officer. A radiologist could also be called from the 1st Auxiliary Surgical Group.

The other field hospital units, of which the one at the "hard" is a component, used elsewhere on the shore, as holding or emergency hospitals, are each expected to have one X-ray technician and equipment. The radiologist should visit or delegate as the situation demands. The radiologist, through the supply officer, should make a provision for obtaining expendable X-ray supplies for all three units.

3. "*Near shore.*" The full field hospital situated away from the "hard" is expected to have one radiologist and adequate X-ray equipment and three X-ray technicians. If sufficient litter bearers are available the X-ray service will be adequate without augmentation, except when continuous service is required; then it should be augmented by an auxiliary mobile X-ray unit.

4. *Station Hospitals.* The X-ray department at the present location of the 38th Station Hospital is not thought to be adequate for heavy continuous X-ray service, partly because of the small amount of equipment, the inadequacy of the quarters, and the difficulty of litter bearing to and from other floors of the building. Especially if this station hospital should be expanded by tentage, an auxiliary mobile X-ray unit could set up close to the front or other entrance or adjacent to expansion tentage.

5. Advise that S. B. S. [Southern Base Section] notify all possible units concerned of the availability of the mobile X-ray units and procedure for procuring their use.

6. One auxiliary mobile X-ray unit should be assigned for disposal to the area surgeon of each area.

By 10 February 1944, the First U.S. Army, then in the United Kingdom, was sufficiently well organized to permit the First U.S. Army Consultant in Surgery to request orientation conferences for the army radiologists. On 19 April 1944, the same request was received from the Third U.S. Army. A number of conferences were held with radiologists in both armies, in response to these requests, and by 20 June 1944, hospital and mobile X-ray units of both armies had been visited.

Shortly before the invasion, a circular letter was published which dealt particularly with the care of patients in forward hospitals (*2*).

FIGURE 156.—Capt. Sidney Cobb, MC, Ward Officer at 44th Evacuation Hospital, studying radiograph of chest in laboratory of 1st Evacuation Hospital in Malmedy, Belgium, December 1944.

SPECIAL PLANNING

Facilities

The following information concerning facilities for evacuation and field hospitals was communicated to personnel of these hospitals in meetings and during personal visits by the Senior Consultant in Radiology and the regional consultants:

Housing.—Evacuation hospitals (figs. 156 and 157) must be arranged to carry out fluoroscopy, radiography, and processing of films at the same time. A satisfactory way to accomplish this requirement is to use a ward tent and

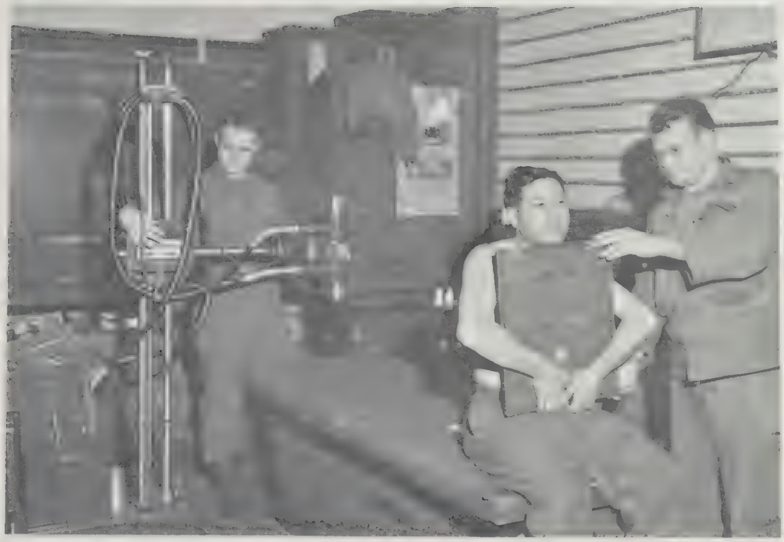

FIGURE 157.—Chest radiograph taken at 102d Evacuation Hospital as part of physical examination for admission to Officer Candidate School, Belgium, January 1945.

two darkroom tents, one for radiography and the other for fluoroscopy, with the processing tent, at least, inside the ward tent. The latter precaution is necessary because the canvas of the tent used for the darkroom is too thin to exclude daylight totally. It is more desirable, when possible, to place both the darkroom and the fluoroscopic tent inside the ward tent. If a second darkroom tent is not available, another inside tent can be improvised by using a latrine screen.

Field hospital units (fig. 158), which have only single X-ray machines, do not require two darkroom tents.

Improvised duckboards are advantageous in the darkroom. Waiting room seats for ambulatory casualties can be made from empty X-ray chests and placed between the darkroom and fluoroscopic tent, as well as along a low side of the ward tent.

During the summer months, when field and evacuation hospitals were in tents, the housing problems, at least for evacuation hospitals, were practically the same as those for general hospitals except that no flooring cement was poured for them. As a result of direct observations on the Continent, the Senior Consultant in Radiology, ETOUSA, and the regional consultants were able to pass on the following information and advice to radiologists in forward hospitals:

FIGURE 158.—Examination of battle casualty before operation with portable X-ray unit in 60th Field Hospital, Saint-Max, Nancy, France, October 1944.

Though listed as only 400-bed hospitals, evacuation hospitals of this size frequently expanded, and the caseload often put X-ray requirements on the same volume level as those of a general hospital, while at times the proportion of litter casualties was much greater. Some hospitals of this size, such as the 35th Evacuation Hospital, near Saint-Sauveur-le-Vicomte, France (p. 444), once had to handle 240 patients in a 24-hour period, and, frequently, during active periods, such hospitals averaged 80 to 100 patients per day. They therefore required practically the same X-ray space as general hospitals; that is, not less than 1,200 square feet of tentage in the field. Since cement was not poured for floors, the flooring had to be improvised from salvaged tents, tarpaulins, straw, sawdust, gravel, or grass.

As in the selection of the location of general hospitals, it was desirable that a radiologist, with knowledge of the special problems of this specialty, should accompany the advance party when buildings were to be selected for hospitals and department space allotted.

If an evacuation hospital took over buildings not originally designed for a hospital, the following points, most of them also applicable to general hospitals, had to be considered:

1. The accessibility of the X-ray department for outpatients and walking wounded.
2. The accessibility of the X-ray department for hospitalized litter patients. In a

multistoried building, the availability or lack of an elevator, the width and pitch of a staircase, and the size of doorways were very important considerations.

3. The distance of the X-ray department from the wards.

4. The proximity of the X-ray department to the operating room. This consideration was often overrated in importance. A different consideration was the proximity of the department to the preoperative and shock wards; it was important that it be close to those facilities.

5. X-ray protection not only for those in the department but also for those in adjacent rooms and above and below it. The proximity of personnel in adjacent rooms was not so important in evacuation hospitals because of the frequent moves of these units.

Power.—Techniques of obtaining the greatest amount of service from table of equipment generators was always a problem and was the subject of much discussion. The distribution of power by improvisation of switches and determination of the proper length and size of wire runs (table 11, p. 441) required study and ingenuity. Radiologists were urged to use central power whenever a large hospital generator was accessible and to utilize local civilian power whenever it was available on the Continent in the proper form. Civilian sources of power could be used more frequently when field unit X-ray machines were wired for both 115 and 230 volts.

Radiologists were urged to exercise the utmost skill in the care and operation of electric generators. The instructions issued with each generator must be carefully studied and precisely followed by radiologists and technicians.

Litter Bearers

The Senior Consultant in Radiology advised all radiologists in forward hospitals to hold conferences with representatives of other services and with the administrative divisions concerning the use of litter bearers for transporting patients to and from the X-ray department. Their provision was always a serious problem. X-ray departments fortunate enough to have litter bearers assigned for their exclusive use were usually able to keep ahead of the demands of the operating room far better than departments which had to use the general pool of litter bearers.

The utilization of prisoners of war, when the hospital was so located that this plan was permissible, was a desirable solution of the difficulty.

Technical Points

Certain practical points were also emphasized to radiologists and technicians:

1. The field X-ray machine could be used more efficiently beside a table if a board or other type of track was improvised to guide its movement up and down the length of the table (fig. 137, p. 385).

2. Film drying would be hastened if a free current of air could be forced through the darkroom by an improvised lightproof trap. The ventilator alone was inadequate.

If the improvisation just described was not feasible, then films could best be dried outside of the darkroom.

3. The use of improvised hose or pipe plumbing with water inlets and drain outlets from the processing units would increase darkroom efficiency.

4. Positions should be standardized according to the guide for forward areas furnished each X-ray department by the Office of the Chief Surgeon.

5. Roentgenograms should be identified accurately according to existing directives (p. 338).

6. All patients evacuated to other hospitals should be accompanied by their roentgenograms (p. 340). A proper filing system in the hospital would make the radiographs readily available to those who wished to see them and at the same time would make it possible, on short notice, for each patient who was evacuated to be accompanied by his films.

PRINCIPLES OF FORWARD RADIOLOGIC SERVICE

Location of Service

In the European theater, the decision was made that X-ray service would be furnished in the forward area wherever a relatively large number of casualties required treatment. As a practical matter, this meant that it would be furnished in any location in which surgery was being done and 100 or more beds were available for postoperative care. If a field hospital meeting this requirement was located in a forward area, provision of radiologic personnel and equipment would be routine. If there was no hospital installation, as at a division clearing station to which auxiliary surgical group teams had been dispatched, X-ray service would be furnished by mobile hospital units. Observations in the Mediterranean theater and experience in the European theater showed that in World War II it was not feasible or desirable to provide X-ray service farther forward than division clearing stations.

Selection of Cases

Colonel Allen strongly recommended that, during quiet periods, planning conferences be held between the radiologists and the surgeons whose function was to sort the patients for treatment and evacuation (triage). He urged that these conferences be continued until a plan had been formulated, and complete understanding reached, as to the order of priority in which patients would be dispatched to the X-ray department. It was also emphasized that patients must be accompanied by enough of their histories to permit accurate positioning and adequate radiography on their first visit. Early in the fighting on the Continent, medical officers frequently failed to furnish the radiologists with enough of these details to permit the proper radiographic positioning. The omission made many reexaminations necessary. The difficulty was gradually rectified by the publication of new directives; visits to hospitals; and new wording of the X-ray request, which now asked,

in addition to the items on the original form (Form ETOUSA MD 55K–2, September 1943), the purpose of the examination. This information permitted proper positioning of the patient on the first examination. As this particular detail indicates, those hospitals in which other medical officers regarded the radiologist as a consultant received the best radiologic service.

INSPECTION OF HOSPITALS AFTER D-DAY

The successful implementation of the SOP prepared for radiology was evident in the inspection tour made by Colonel Allen to transient, general, station, evacuation, and field hospitals on the near shore during the first 19 days after D-day. All of these hospitals acted as forward hospitals and received casualties from LST (landing ship, tank) cross-Channel ships. Entries from his official diary follow.

12 June 1944

38th Station Hospital

Proceeded to 38th Station Hospital. This is a transit hospital and is receiving a large number of casualties. Up to the present the X-ray department, although inadequately housed, has not impeded the progress of patients through this hospital for evacuation. The use of the auxiliary mobile X-ray unit as an adjunct here was discussed with the commanding officer and radiologist, both of whom felt that they might need to call for one if the work became heavier. The quality of radiographs and interpretation is satisfactory at the present time, but the technicians appeared to be tired, and if demands continue some relief by means of the mobile X-ray unit will probably be necessary. The processing capacity has been improved since the last visit. On 11 June this department completed 85 cases. The hospital was unable to get 8 x 10 and 10 x 12 films and was advised to make an emergency requisition of Maj. [D. P.] McGill of Supply Division. A planning conference was held with the Chief of Surgery and the commanding officer to arrange a system of priority of X-ray requests in order of operations due. This hospital has been instructed to mark their films according to the location site rather than their unit. The evacuation of X-ray films with the patient is completed by receipt of a list of names from the registrar, but one hundred percent efficiency cannot be reached because there are a number of last minute changes in the evacuation of patients.

46th Field Hospital

Proceeded to the 46th Field Hospital. Capt. Palmer D. Miller, the radiologic officer, is also in charge of pathology. There has been a heavy flow of patients, and he finds that three technicians are inadequate. The commanding officer has permitted him to use the electric power maintenance man as an extra and another extra to act as clerk. This hospital has improvised a block support for both ends of the radiographic table to hold the litters with steel loops high enough to permit the grid to move the length of the table. An excellent film drying system has been improvised by a rack in front of the 3 kw. electric light generator, which blows the blast of air through the radiator onto the films. By this method, films often dry in 10 minutes. The Senior Consultant in Radiology has communicated this system to other transit hospitals. The commanding officer and radiologist were notified of the possibility of requesting the auxiliary mobile

X-ray unit if and when requests for X-ray cannot be dealt with promptly. On the whole good X-ray service is being rendered by this hospital, and it is commensurate with the general demands upon the hospital.

28th General Hospital

Visited 28th General Hospital. Upon receipt of the first admissions of casualties the X-ray department was requested to make *400 X-ray examinations in 24 hours.* This was about 90 percent of admissions and was based on a policy to use X-ray for a principal triage agent; the commanding officer and the radiologist had prevailed upon the chiefs of surgical and medical services *not to use X-ray for triaging,* but only when it added evidence concerning treatment, except in rare instances. At the present time requests for about 50 percent of admissions are sent immediately to X-ray. After the first 24 hours the department was able to cope with the heavy demands and evacuations are not impeded. Capt. [later Maj.] Benjamin Felson was greatly assisted by the presence of an assistant,[3] placed in the department * * *. Because of this student, who has shown a fine aptitude, no additional officer personnel is necessary in the department now. The following subjects were considered with Captain Felson: Methods of drying films in the least possible time, such as improvised drying racks with clips on strings, placing of dried films in the ward available to the surgeons as necessary, and evacuation of films with each patient. Since, during heavy loads, the radiologist is required to read wet radiographs, he then dries them and sends them direct to the patient's bed and the films are evacuated with the patient by the ward surgeon. *Further study of receiving hospitals will be necessary to evolve the best plan for keeping the films with the patient.* The hospital is low on holders, film development. It was advised that the supply officer call the Supply Division, Office of the Chief Surgeon, for an emergency requisition. Except for the first two days this department has functioned smoothly and is satisfactory throughout.

13 June 1944

95th General Hospital

Visit to 95th General Hospital. This hospital has had no casualties and only 60 patients, although it is only 6 miles from the 28th General Hospital which has handled 1,600 casualties. Col. [later Brig. Gen.] Edwin H. Roberts, the Commanding Officer, does not know why they have not had casualties. The X-ray department is apparently prepared. The radiologist was apprised of the early difficulties encountered by the 28th General Hospital. The subject of large numbers of radiographic cases with accompanying film drying, sorting and dispatching with patients was discussed at length. The subject of using X-ray for triage was discussed with the commanding officer, and he will make an effort to prevent deluging the X-ray department with unnecessary X-ray examinations if and when this transit hospital is used for casualties.

50th Field Hospital

Proceeded to 50th Field Hospital. This is set up in two locations; one close to the hard and the other above 3 miles away. The one at a distance is prepared to do X-ray

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[3] This assistant was Capt. (later Maj.) Emanuel J. Levin, MC. He had had no radiologic training at this time. After the war, he trained with Dr. Felson in Cincinnati. Later, he became Professor of Radiology at the New York State College of Medicine and Director of the Radiological Department, Maimonides Hospital in Brooklyn. It was repeatedly observed that medical officers without previous training in radiology became so interested in the specialty when they were exposed to it during the war that they continued with it in civilian life.

work to the standard required by two units of a field hospital. Their X-ray arrangement is good. The radiologic officer in charge, Capt. Robert Biddle, has had a 6 weeks' course with Col. Alfred A. de Lorimier [MC] and has a good X-ray technician with each unit. It is believed that they will be able to furnish quite good radiographs, but will need help with interpretation wherever they may be. The unit on the hard was found by Lt. Col. [George K.] Rhodes [MC] to need reinforcing very badly, so an auxiliary mobile X-ray unit was ordered. Within 6 hours of the request the unit arrived, and within 1 hour of its arrival it had produced the first radiograph. Fifty radiographs were made the first night and upon review were found to be as good as the average hospital radiographs. The officers of the field hospital platoon were well pleased with the service rendered by the mobile X-ray unit commanded by Capt. William G. O'Donnell [MC]. The unit was situated near the hospital X-ray tent, surgery and ward tents. It seems to be easy to place the mobile unit in a strategic position in relation to a hospital. The officer and technicians were handling the unit well and had evolved technique for making radiographs with the least possible disturbance of the patient. Each technician was assigned certain special work in setting up and in maintaining service to the hospital, and assignments were rotated to insure one's being capable of handling any requirement of the unit.

12th Field Hospital

Proceeded to the 12th Field Hospital. The X-ray department here is set up in four pyramidal tents with continuous sides and walls rolled up to make one large room. This was connected with a common waiting tent, with pharmacy and laboratory attached thereto so that all patients waiting for pharmacy, laboratory and/or X-ray used the same waiting space. This was an efficient arrangement. The radiological officer, Capt. Sidney Dann [MC] is a 6 weeks de Lorimier course man, who should be able to make radiographs and keep his technicians fairly well trained. He will be unable to interpret many cases. It would seem that field hospitals will often require the use of an auxiliary mobile X-ray unit. At the time of this visit the hospital was in the act of moving to another site.

12th Evacuation Hospital

Proceeded to the 12th Evacuation Hospital. The X-ray Department of this hospital was handling about 90 radiographic cases per day in its tent X-ray department. The radiographs were of good quality and exceedingly well interpreted. The arrangement of the department is good throughout. Both Maj. [later Lt. Col.] Frank Huber and Capt. Charles Huntington are busy, demonstrating that a 750-bed evacuation hospital requires two radiologists when used near capacity. Of the first groups of casualties received, X-ray examinations were requested on about 90 percent of the cases, but after conference between the commanding officer, chiefs of service and radiologists, the requests for X-ray were reduced to about 50 percent of admissions. A general survey of the situation indicated that they were still requesting too many X-ray examinations in this hospital, because many patients were evacuated before treatment, based on X-ray findings, could be instituted. This appeared to be a strong hospital unit and the quality of the X-ray service was commensurate with the unit as a whole.[4]

28th Field Hospital

Visited 28th Field Hospital which had only had a total of 30 casualties. No radiogist serves this hospital, but the commanding officer and chief of the surgical service

[4] See history of this hospital, p. 450.

could and did call on Captain Miller of the 46th Field Hospital to supervise the work of the X-ray technicians. For radiographs which they cannot interpret they will call on Captain Miller. Should a change in the tactical situation deluge the department, they will request the use of the auxiliary mobile X-ray unit. Lt. Col. [later Col.] Einar C. Andreassen, MC, Southern Base Section, had asked the Senior Consultant to see if a radiologist should be sent to the 28th Field Hospital, but it was found unnecessary because of the proximity of the 46th Field Hospital.

109th Evacuation Hospital

Proceeded to the 109th Evacuation Hospital. The radiologist here, 1st Lt. Edward D. Greenberger [MC] has been a board member for 7 years and in the Army for 3 years without promotion. The commanding officer broached the subject and stated that he had done all in his power to have this officer promoted and hopes he will be soon. The X-ray department was exceedingly well run, well arranged and with some good innovations in housing. The radiography and quality of interpretation was excellent throughout. The radiologist here is successfully using optimum voltage X-ray technique.[5]

40th Field Hospital

Proceeded to the 40th Field Hospital, where a detachment of one unit is serving a nearby airfield and has received only 9 cases. There is no radiologist, but one X-ray technician has the department fairly well set up.

14 June 1944

228th Station Hospital

Visited X-ray department of 228th Station Hospital. This hospital, like many, requested X-ray examinations on a higher percentage of admissions on the first few convoys arriving than on later convoys after the work of triage became more clinical and systematized. However, 400 X-ray examinations have been made in the first 7 days after the arrival of the first casualties. The X-ray department is preparing to handle 150 radiographs per day if it becomes necessary. This is thought to be too optimistic for continual service. Capt. Everett L. Pirkey, MC, has evolved an excellent method of arranging films for transport with the patient. Black paper and a copy of 55K–2 (X-ray report) is stapled to the X-ray film with the patient's name on the outside. This hospital X-ray department can handle more casualties because eight litter bearers have been assigned to it with nothing to do but handle X-ray cases, and all eight are continually busy. There are four teams of two men each and their hours are staggered so that there is complete 24-hour service. The hospital is still requesting seemingly unnecessary radiographs on patients. This was discussed with the commanding officer.

305th Station Hospital

Proceeded to 305th Station Hospital. This hospital has handled 1,600 cases and has a 12-mile trip from hospital to train. There have been 472 cases examined by X-ray in the week it has been in operation. The radiologist[6] and the technicians are very tired. Relief by either a mobile X-ray unit or a temporary transfer of radiologist was not

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[5] As recommended by Mr. Arthur W. Fuchs, Eastman Kodak Co.
[6] Capt. (later Maj.) Henry G. Ford, MC.

thought necessary at the time, and no such offer was made, but the personnel was advised to call for assistance when needed through the Southern Base Section. Although the radiography was not as good as at some hospitals equally busy, it was improving and means of improvement were suggested by the Senior Consultant. Extreme fatigue in the department is believed to have been the cause of some poor radiographs. All had had a night's rest preceding this visit and now felt able to control the situation. Another handicap for optimum operation of the X-ray department is the hospital shortage of litter bearers. Arrangements for drying are quite good, but probably increased drying capacity will eventually become necessary. This could be achieved by improvising drying facilities other than those already used; namely, a closed drying rack in the blast of the regular drier. This hospital has X-rayed about 35 percent of the casualties received.

315th Station Hospital

Visit to 315th Station Hospital. This hospital has received 2,500 casualties, and there have been less than 10 percent requests for X-ray examinations. That may seem low, and the subject was discussed with the commanding officer and radiologist.[7] However, the hospital is purely for transient airborne casualties. Only those who cannot travel further are subject to X-ray examination. Their evacuation system was smooth and rapid, and cases in which X-ray definitely would not affect treatment were not sent for X-ray. It is believed that there will be more use made of X-ray in the future as the radiologist was advised that soft-tissue wounds should have X-ray study before surgery. The department is well managed and well arranged, except that the partitioning is such that fluoroscopy cannot be done without blocking the darkroom entrance. * * * However, there has been very little fluoroscopy. Interpretation is good and the radiography is good throughout. Films are sent to the surgery for reviewing by the surgeons during operations and are transported forward with evacuated patients in bundles wrapped in black paper with the patient's name on the outside. This hospital has the personnel divided into three shifts, each working 16 hours per day so that there is always an overlap of personnel to transfer information on patients back and forth. This was a novel use of personnel. If at any time their work permits, personnel can rest some during the four hours preceding or four hours after their regular 8-hour shift.

SUMMARY OF OBSERVATIONS

A summary of his observations in hospitals on the near shore immediately after D-day was sent by Colonel Allen to the theater Chief Surgeon on 24 June 1944, as follows:

1. Conditions for correction, in transit hospitals especially, but existing also to some extent in rearward hospitals:

a. Too high a percentage of cases is X-rayed when large numbers of casualties are admitted at once, especially in "uninitiated" hospitals. This percentage drops as admission numbers drop and as experience in receiving convoys is gained. Too many cases were X-rayed in which treatment was not affected, occasionally just prior to evacuation. There will, of course, always be a few cases in transit hospitals for which X-ray is necessary in order to help decide whether to evacuate or not. In rearward hospitals many cases will require X-ray to decide whether to return to duty or evacuate to the ZI.

b. Not enough X-ray examination of soft-tissue wounds before debridement in transit hospitals.

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[7] Capt. (later Maj.) Robert W. O'Connor, MC.

c. Difficulties have been encountered in transfer of X-ray films so that they are available to the new hospital when the patient arrives. Effort is being made to get a consensus from train commanders and hospital- and center-receiving officers as to whether a transit hospital should send films in bundles with each convoy or with each patient separately. Further information is requested from any possible source, by other consultants and medical officers. It would seem from the evidence at hand that films with each patient have fewer failures than when given to train commanders in bundles.

d. A paucity of litter bearers to transfer patients to and from the X-ray department itself. At the 228th Station Hospital [8] eight litter bearers are assigned to X-ray, and there the department has functioned smoothly in spite of very heavy work. A bottleneck in X-ray keeps beds from emptying.

e. The auxiliary mobile X-ray units can be called for by any of the transit hospitals, field, evacuation, station or general hospitals.

f. Rearward hospitals have found films [9] very diagnosable and in an increasing percentage. However, there is much room for improvement.

The Senior Consultant in Radiology, ETOUSA, observed throughout the war that the nearer to the front radiologic facilities were provided, the more frequently did medical officers use radiologic examinations for the triage and disposition of patients. He also noted that inexperienced medical officers ordered more radiographs for the purpose of deciding the disposition of casualties than did experienced officers. Most of them quickly learned, however, from conferences with the chiefs of surgical and X-ray sections, that only very occasionally should radiologic examination be used for purposes of triage.

In his annual report for 1944, the Senior Consultant in Radiology, ETOUSA, also noted that medical officers soon learned the fallacy of sorting and classifying patients by radiographic findings alone. As hospital staffs gained experience, the percentage of requests for X-ray examination of newly arrived patients uniformly and steadily lessened during the first 48 hours after their arrival. Experience showed that in a convoy of 300 casualties, made up of freshly wounded patients, requests for 50 percent of the cases were not too much. It was expected, however, that, as transmittal of radiographs from forward hospitals with patients became increasingly efficient, the percentage of requests for examination in rear echelon hospitals would drop to 25 or 30 percent.

Visits to forward areas by the Senior Consultant in Radiology, ETOUSA, during June and July 1944 made clear that neither personnel nor equipment was adequate for the volume of radiologic work required. The deficiencies were made up in two ways: (1) By use of mobile X-ray units and (2) by arbitrary assignments of more officers and men to the X-ray department by commanding officers, in spite of the need for personnel elsewhere.

Film drying was found to furnish a serious delay in the triage, treatment, and evacuation of casualties. It was again emphasized to radiologists and technicians that this process could be expedited by forcing air through the developing tent or by hanging films on wires by clips or by safety pins.

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[8] Capt. (later Maj.) Everett L. Pirkey, MC, radiologist.

[9] Made in forward hospitals and accompanying patients.

It was also emphasized again that wet films should be taken to the operating room if surgeons requested them. Future planning might incorporate facilities to permit this type of surgical-radiologic cooperation.

Diagnostic difficulties.—Contrary to prewar expectations, casualties were frequently received in evacuation hospitals with injuries and complications difficult of interpretation. Such conditions as traumatic aerocele of the brain and bizarre types of pneumothorax and pneumoperitoneum are not often encountered in civilian practice.

Speed in the examination of patients was essential, in order not to delay surgery and, in turn, the evacuation of patients. Often, therefore, for days on end, it was necessary to make hurried interpretations of wet films. Speed and the interpretation of wet films were both unfavorable factors, and some errors in diagnosis resulted, but, on the whole, they were remarkably few.

Fortunately, most diagnostic radiology in evacuation hospitals was relatively simple. Nonetheless, if the X-ray department was to meet the heavy demands upon it, there was need in each such hospital for at least one experienced radiologist possessed of energy, skill and ingenuity. As pointed out elsewhere, although many older men stood up well under the strain, it was desirable, whenever possible, that radiologists assigned to evacuation hospitals be under 35 years of age.

REFERENCES

1. Report, Lt. Col. K. D. A. Allen, MC, to Chief Surgeon, ETOUSA, 25 Oct. 1943, subject: Visit to NATOUSA, including the 5th Army Medical Installations in Italy, by the Senior Consultant in Radiology, ETO.

2. Circular Letter No. 71, Office of the Chief Surgeon, Headquarters, European Theater of Operations, U.S. Army, 15 May 1944, subject: Principles of Surgical Management in the Care of Battle Casualties.

CHAPTER XV

Radiology in the Communications Zone on the Continent

Kenneth D. A. Allen, M.D.

GENERAL CONSIDERATIONS

In World War II, radiology in rear areas differed materially from radiology in forward areas, while in rear areas, radiologic service in general hospitals differed considerably from that called for in station hospitals. One important reason for the latter difference was that elective surgery was limited to general hospitals. Since the diseases which required elective surgery usually entailed more refined X-ray diagnoses, especially when the thicker parts of the body were involved, more experienced radiologic interpretation was required. As a rule, patients had to be referred to general hospitals for gastrointestinal, gallbladder, and renal studies; for encephalography; and for the localization of intraocular foreign bodies.

After 6 June 1944, the radiologic work of station and general hospitals became more closely equalized. Some units in both categories were necessarily designated as transit hospital (p. 427), whose primary function was to examine casualties as they arrived in the United Kingdom and to decide whether they could withstand further transportation from airstrips and ships to more specialized hospital centers. Most patients whose transportability status was not immediately apparent required X-ray examination, which was carried out in the same way in all transit hospitals, whether they were station or general.

Frequent changes in the function of hospitals and in their specialized assignments, as noted elsewhere (p. 349), required constant reevaluation of the special qualifications of radiologists assigned to these hospitals as well as of the equipment allotted to them.

FACILITIES

Early in 1944, it became necessary to prepare radiologists assigned to general hospitals and, to a lesser degree, to station hospitals scheduled for movement to the Continent, for the establishment of their departments in the field after the invasion. There were no plans available for the operation of X-ray departments under such conditions. The Senior Consultant in Radiology therefore spent much time with the radiologists in the theater and with the

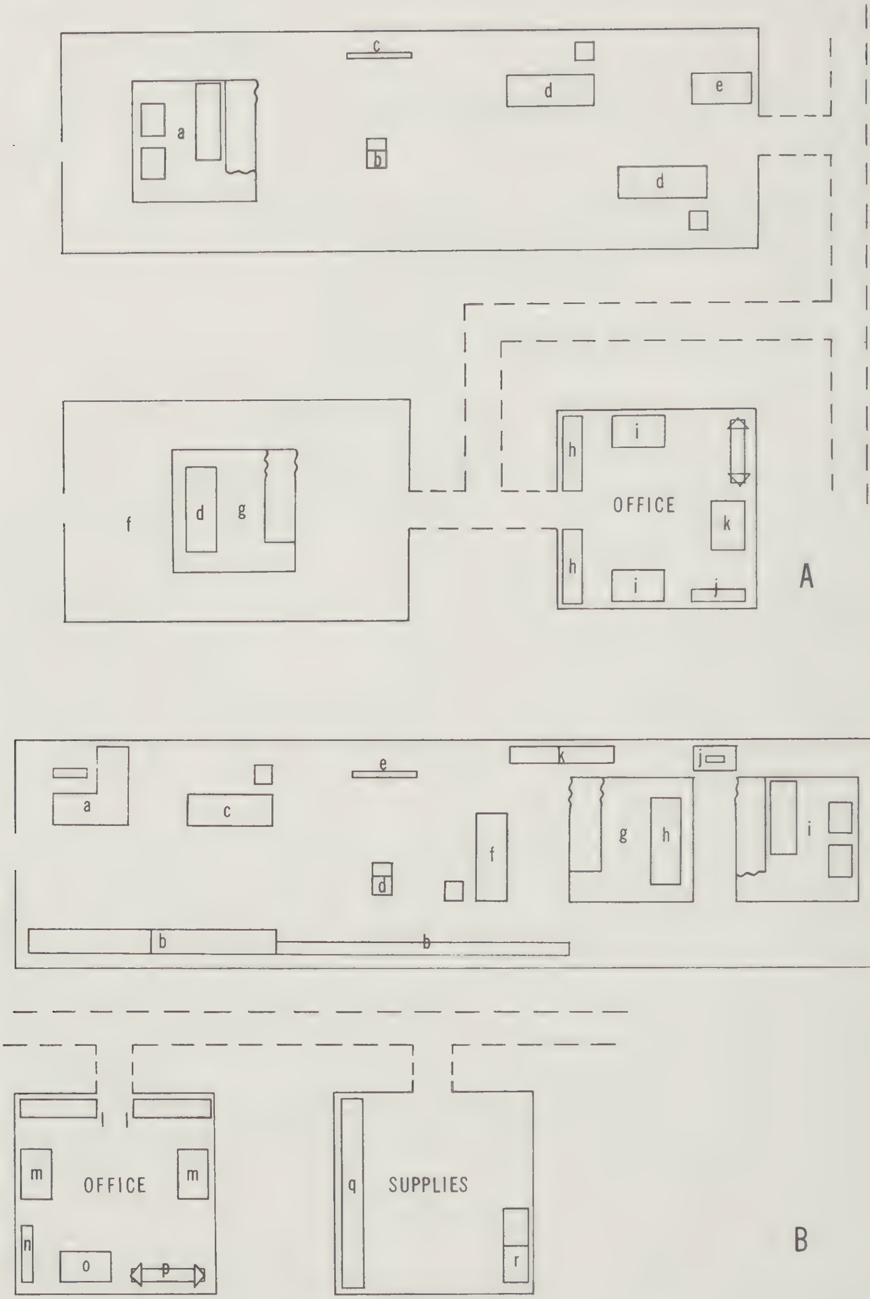

FIGURE 159.—*See opposite page for legend.*

appropriate sections of the Chief Surgeon's Office, European theater, planning for field housing, for water supply and drainage, for power, for darkrooms, for film drying, and for general arrangements (fig. 159). A great deal of emphasis was put upon the expected necessity for improvisations in both equipment and facilities.

It had been assumed by the Construction Section, Hospitalization Division, Office of the Chief Surgeon, that, within a few weeks after the invasion, the operating room and the X-ray department of each hospital would be moved to prefabricated huts from the tents originally used. The Construction Section drafted designs and made blueprints for the X-ray department on this basis, including plans for wiring, plumbing, protection, and general arrangements.

On the assumption that the transfer from tents to huts could be anticipated shortly after the invasion, Lt. Col. (later Col.) Kenneth D. A. Allen, MC, consented to the housing of X-ray departments in single-ward tents as a temporary measure. The Construction Section thereupon instructed the engineers to pour cement flooring in the shape and size of single-ward tents. It was promptly evident that these tents would be inadequate for permanent use, and when it was learned, as it soon was, that the expected fabricated huts would not be available, efforts were directed to providing more suitable housing. One or the other of the following plans was used:

1. Cement was poured for the flooring of two squad tents placed end to end, with one or more subsidiary storage or large wall tents.

2. Two ward tents were erected side by side ("married"), with the inner canvas between them rolled up to convert them into one large tent. This plan was the better of the two, one reason being that ward tents were more easily procured in the European theater than other types, and it was generally followed.

Concrete flooring was poured in advance, in accordance with the type of tent to be used.

On 10 February 1945, the following communication was sent by Colonel Allen to Col. Bryan C. T. Fenton, MC, of the Finance and Supply Division, Office of the Chief Surgeon:

> In case there might be further tent * * * hospital installations, the undersigned is considering what shape and size * * * cement flooring be made for X-ray departments.

FIGURE 159.—Floor plans of X-ray departments of general hospitals in the Communications Zone, France. A. Floor plan of 5th General Hospital: Darkroom (a), chest machine (b), cassette changer (c), X-ray machines (d), receiving desk (e), squad tent (f), fluoroscopic tent (g), film files (h), desks (i), file (j), and typist's desk (k). B. Floor plan of 50th General Hospital: Receiving desk (a), benches (b), X-ray machine (c), chest machine (d), cassette changer (e), X-ray machine (f), fluoroscopic tent (g), fluoroscopic machine (h), darkroom (i), drier and viewbox (j), supply shelves (k), film files (l), desks (m), file (n), typist's desk (o), stereoscopic viewer (p), supply shelves (q), and sink (r).

Could you ascertain for me whether to obtain storage tents to place end to end, or ward tents to place side by side. K. D. A. A.

Colonel Fenton replied on 12 February 1945: "* * * relative to basic IRS [Internal Routing Slip], Tent Ward has been in better supply in the theater, and it is felt future plans should be based on that type tent."

Specifications

The following general information concerning the criteria of housing of fixed hospitals in the field was communicated to radiologists in meetings and at personal visits by the Senior Consultant in Radiology and the regional consultants:

Location.—A central location is desirable for the X-ray department, so that it will be accessible to the receiving room, the operating room, and the wards. As a rule, this arrangement is easily achieved in the construction of tented hospitals, but it is sometimes a problem in buildings not designed primarily as hospitals. In multistoried buildings, it is often best to place the X-ray department on the first floor, for two reasons: (1) to simplify the handling of outpatients and (2) to avoid exposure of personnel working underneath the department. The availability or lack of an elevator has much to do with determining the selection of the floor on which the department is to be located.

If sufficient space is not available for protection of personnel by distance, reliance must be placed on ray proof walls, on lead or barium plaster-protected exposure booths, and on lead rubber aprons on improvised frames (p. 387).

Other factors to be taken into consideration are plumbing, powerlines, and varying building designs.

Space.—One of the most important considerations in construction of an X-ray department in any type of installation is securing enough space. This necessity is obvious enough to a radiologist, but is frequently disregarded by persons ignorant of radiology who design these departments. Adequate space is necessary for several reasons:

1. Waiting room space must be provided for ambulatory patients and for the large numbers of litter patients to be expected.
2. Several X-ray machines (up to five when available), a cassette changer, and protective lead screens occupy so much space that it is difficult to handle both patients and equipment if there is not enough space to separate them from each other.
3. A lightproof processing room must be provided, as unexposed film fogs quickly in cramped quarters. A fluoroscopic room is also necessary.
4. If there is insufficient protective distance, radiologic personnel will be exposed to the dangers of both primary and secondary radiation.

Design.—The following arrangements are desirable:

1. The reception space and clerk's station should be placed at the same entrance and as far as possible from the source of X-ray exposure.

2. A central off-duty station for technicians and an additional storage room can be situated in a separate pyramidal tent, if it can be procured, without loss of utility.

3. A separate radiologic office, in a small canvased partition or a separate tent, is advisable. Films can be stored in this space.

4. Whenever possible, a latrine in a nearby tent should be used solely for patients requiring barium enemas.

5. If cement is used for the floor, it should be poured as smoothly as possible, to facilitate moving small-wheeled X-ray machines. If cement is not available, salvaged tarpaulin, canvas, or sawdust can be used for flooring. If the tent is set up when the ground is dry, a grassy space is more desirable than bare ground.

6. When buildings not primarily designed to house X-ray departments are used for this purpose, considerable variation in the standard arrangements is necessary. If it is possible, it is always desirable to have separate rooms for receiving patients; fluoroscopy; darkroom; supply room; office; and exposure rooms, two or three being provided when space permits. This arrangement is not a matter of convenience only; unless the original walls are radiolucent, unpartitioned space increases problems of protection.

7. Whenever a new building is taken over, the walls and partitions should be immediately tested for radiopacity. The mazes and pass boxes necessary in an X-ray department can be easily constructed either by the engineers who set up the hospital or, if they are not available, by hospital utilities personnel or even by X-ray personnel. If there is more than one exposure room, a central location for the darkroom can be achieved by knocking out partitions.

8. Special attention should be devoted to wiring, since the size of the wires that carry power to the X-ray department are extremely important to its proper functioning.

9. An advance party seeking housing for a hospital should always be accompanied by a radiologist, because of the special problems of the radiology service. Careful planning and forethought can generally avoid a poorly functioning X-ray department that might well become a bottleneck and slow up initial wound surgery.

First Installations

The 5th and 50th General Hospitals, Carentan, France, the first fixed hospitals to be set up on the Continent, were housed in ward tents and two squad tents, placed end to end; cement floors in this design were poured before the tents were set up.

At the 5th General Hospital, a squad tent was obtained for fluoroscopy and for the storage of supplies (fig. 159A). The general-issue main tent did not exclude direct sunlight.

At the 50th General Hospital (fig. 159B), additional pyramidal tents were supplied, one of which was used as an office and the other for supplies. The commanding officer also allowed the replacement of a squad tent by a ward tent. For long periods, an average of 100 patients per day were examined, and many outpatients were crowded into the tent at one time, especially in inclement weather. Even with the additional tents provided, space was therefore at a premium, and the technicians were hampered in their work.

EVALUATION OF FACILITIES

The experience of the 5th and 50th General Hospitals made it clear that the minimum space for an X-ray department in a general hospital, whether

the installation was temporary or permanent, was 1,200 square feet. The Hospitalization Division, Office of the Chief Surgeon, was requested thereafter to pour cement flooring to allow two ward tents to be set up side by side (p. 437), instead of providing for the end-to-end arrangement of squad tents first used. Not only was the side-to-side arrangement more efficient but, as already noted, ward tents were more easily procured in the European theater than other types of tents. By proper modification of sideboards and tent poles, the space available was used to the maximum, and adequate provision was made for drainage during rainy weather.

Many housing problems had to be solved after the invasion of the Continent, and they were multiplied when the armies moved forward and fresh situations were confronted. This was true even when, as advised, a radiologist was included in the advance party searching for satisfactory hospitalization.

Available buildings varied considerably in convenience, and many of them were by no means modern. The X-ray departments had to be adapted to the space and facilities that existed. Considerable ingenuity on the part of the radiologic staffs was required to provide (1) protection for personnel; (2) adequate electric power; (3) heating, to keep the patients warm and prevent shivering, for clinical as well as radiographic reasons; (4) hot water for barium enemas; and (5) a satisfactory fluoroscopic room. Even when, as occasionally happened, modern hospital buildings were available, with good facilities for civilian work, military hospitals had certain additional requirements, which had to be met by improvisation.

The housing of X-ray departments in fixed installations built by the British is discussed elsewhere (p. 334).

Toilet facilities were generally inadequate. In the south of France, where the standing or squatting toilet was frequently used, it was necessary to build wooden seats over the formerly seatless plumbing. One hospital, located in a former elementary school, had to contend with miniature toilets that had been installed originally for children 6 to 10 years of age. In most installations, the toilet was located so far from the fluoroscopic room as to constitute a real problem for patients who had had barium enemas.

As a rule, the X-ray departments of station and general hospitals in the theater utilized the central hospital powerplants, though the lead wires to the department were frequently too small to carry the current load. To overcome this difficulty, the Construction Section, Hospitalization Division, Office of the Chief Surgeon, was supplied with the information contained in table 11.

REQUESTS FOR RADIOGRAPHS

On 10 June 1944, Circular Letter No. 80, Office of the Chief Surgeon, laid down certain instructions for the use of X-rays in rear echelon hospitals (*1*). In substance, it was pointed out that regulation of the order and volume of requests for X-ray examinations could be accomplished by attention to certain considerations:

1. A request for X-ray examination should be made only if the findings would affect the treatment or, occasionally, the disposal of the patient.

2. Patients in shock or impending shock should not have X-ray examinations except in emergency.

3. Conferences should be arranged between radiologists and those responsible for triage in each hospital to insure uniform policies concerning the types of casualties who should have X-ray examinations; the priorities for various types of casualties; and the numbers in which they should be sent to the X-ray department. Each request should convey to the radiologist the specific purpose of the examination.

TABLE 11.—*British and United States wire sizes*

U.S. allowable carrying capacities of copper wire				Equivalent British current rating				
				British conductor				
Rubber insulation (amperes)	Other insulation (amperes)	U.S.A. B & S gage	Cross section (sq. in.)	Normal cross section area (sq. in.)	Number and diameter (in.) wires	British current (amperes)	Approximate length for 1 volt drop (feet)	Use
225	325	0000	0.1257	0.3	37/.109	240	99	
175	275	000	.1087	.2	37/.083	184	98	
150	225	00	.0951	.15	37/.072	152	(1,000′ run) 97	200-ma. X-ray machine, heavy machine tools, etc.
125	200	0	.0825	.12	37/.064	130	(750′ run) 94	
100	150	1	.0707	.1	19/.083	118	(500′ run) 92	
90	125	2	.0598	.075	19/.072	97	(400′ run) 86	
70	90	4	.0423	.06	19/.064	83	(200′ run and under) 80	
50	70	6	.0290	.03	19/.044	53	60	
35	50	8	.0201	.015	7/.052	37	45	X-ray field unit, dryer, processor, motors, sterilizers.
25	30	10	.0129	.01	7/.044	31	39	
20	25	12	.0085	.007	7/.036	24	33	
15	20	14	.0050	.005	7/.029	15	34	Heaters, small motors.
6	10	16	.0032	.002	3/.029	5	47	Lamps, lights.
3	5	28	.0018	.001	1/.036	3	40	

Source: Condensed from the tables of the U.S. National Board of Underwriters and the British Association of Supervising Electrical Engineers.

4. A similar system should be worked out with ward medical officers.

5. A procedure should be instituted whereby radiographs would be quickly available for transmittal with patients when convoys were to be transferred to

other hospitals. The plan would obviate many reexaminations at hospitals farther to the rear.

6. Radiography should be standardized according to guides furnished each hospital by the Office of the Chief Surgeon.

Attention to these instructions, it was pointed out, would have two desirable effects:

1. It would spare patients pain and discomfort by reducing unnecessary examinations and unnecessary trips to, and waiting in, X-ray departments.

2. It would conserve X-ray films and tubes, as well as the time of radiologists and technicians.

Special instructions were given for regional wounds:

1. Casualties with wounds of the upper thighs and buttocks should have additional anteroposterior or posteroanterior radiographs of the pelvis and lower abdomen, which were frequently involved in these wounds.

2. Casualties with wounds of the thorax should have additional anteroposterior and lateral radiographs of the upper abdomen because of the frequency of transdiaphragmatic involvement.

3. Casualties with wounds of the upper arm, shoulder, and neck should be considered as candidates for additional anteroposterior or posteroanterior radiographs of the thorax, to exclude involvement of the upper lung.

4. All casualties with wounds of the soft tissues of the extremities should have anteroposterior and lateral radiographs of the injured parts, including the nearest joints, before surgery. There should be few exceptions to this rule.

5. Transportable casualties with wounds of the face and skull should not, as a rule, be examined radiographically until special treatment is available for them.

In general hospitals, young and inexperienced officers in medical sections were inclined to request far too many gastrointestinal X-ray examinations, especially barium enema studies. Usually, the situation was brought under control by the cooperation of the Senior Consultant in Medicine.

FUNCTIONING OF X-RAY DEPARTMENTS IN GENERAL HOSPITALS

The functioning of an X-ray department in a general hospital was well set forth in a working manual prepared by Lt. Col. Magnus I. Smedal, MC, Chief of Radiology at the 5th General Hospital. The practical details of the operation of a typical department in a fixed hospital were outlined by Maj. (later Lt. Col.) Charles L. Hinkel, MC, Chief of Radiology at the 98th General Hospital, when it was located at Hermitage, near Newbury, Berkshire, England. This report is particularly valuable because of its clear-cut delineation of the function of an X-ray department in relation to the operation of the whole hospital. Like all other source material in this section, both of these reports are on file in the General Reference and Research Branch, The Historical Unit, U.S. Army Medical Service, Walter Reed Army Medical Center, Washington, D.C.

REFERENCE

1. Circular Letter No. 80, Office of the Chief Surgeon, Headquarters, European Theater of Operations, U.S. Army, 10 June 1944.

CHAPTER XVI

Special Experiences of Evacuation Hospitals

Frank Huber, M.D., Charles G. Huntington, M.D.,
and *Robert W. Lackey, M.D.*

The accounts which follow, one of a 400-bed semimobile evacuation hospital and the other of a 750-bed evacuation hospital, tell the typical story of hospitals in these categories. The (somewhat condensed) data were secured from the official annual reports, prepared by Dr. (formerly Lieutenant Colonel, MC) Robert W. Lackey for the 35th Evacuation Hospital and by Dr. (formerly Lieutenant Colonel, MC) Frank Huber and Dr. (formerly Captain, MC) Charles G. Huntington for the 12th Evacuation Hospital.

35TH EVACUATION HOSPITAL

The 35th Evacuation Hospital, a 400-bed semimobile unit, underwent the usual maneuver training in the Zone of Interior in the Tennessee mud. During this period, personnel of the X-ray Department, whose director was 1st Lt. (later Lt. Col.) Robert W. Lackey, MC, became familiar with their equipment and with its use in the field. Later training in England brought them to an optimum degree of efficiency and morale. The time and effort spent in both training periods paid off many times after the unit was assigned to support troops in combat on the Continent.

The X-Ray Department of the 35th Evacuation Hospital was in operation on the Continent for 227 combat days. This hospital participated in all five major campaigns in Normandy, northern France, the Rhineland, the Ardennes, and Central Europe. In all, it moved 17 times. It remained at Nancy, France, for 67 days, but moved 16 times during the remaining 160 days of the war, averaging only 10 days' operation in each location. During the 227 days of combat operation, it processed 21,325 frontline casualties and made 31,328 radiographs.

Operations on the Continent

Movement to Continent.—The 35th Evacuation Hospital (fig. 160) sailed from Southampton, England, for the Continent, on 18 June 1944, D+12. It was forced to wait in convoy off Omaha Beach on the far shore for 5 days

FIGURE 160.—Experiences of 35th Evacuation Hospital. A. Normandy beach on which hospital landed. B. Flares from German planes, with return fire from U.S. artillery, night of breakthrough in Normandy. C. Hospital set up in field. Officers' tents are in upper left corner, along river, with enlisted men's tents to right. Center cross of tents represents operating room, with X-ray tent in line with it in front row. D. Hospital set up in field in winter. E. German plane shot down in field near hospital. F. Radiographic examination of casualty with wounds of both legs (both were broken and shell fragments had to be removed from both). Examination is being made with patient still on litter on which he was placed when he was picked up, and the dressings are those put on in the field by the aidman. Note cassette under right leg. G. Hospital darkroom. H. Radiograph of wound of shoulder, showing foreign body in situ. I. Initial wound surgery on patient with shoulder wound shown in view H.

because inclement weather made landing impossible. During this period, beach and bay were under constant enemy bombardment, and one ship in the convoy was sunk, unfortunately the one which contained most of the hospital equipment.

The unit finally landed on the beach on 23 June 1944, D+17, and remained there in bivouac for the next 48 hours while the Supply Section assembled enough reserve equipment to set up the hospital. The chief X-ray technician "borrowed" the X-ray equipment of another evacuation hospital which was not then on the beach and not scheduled to go into operation for several weeks.

Saint-Sauveur-Le-Vicomte.—On 24 June, the hospital was ordered to proceed by motor convoy to Saint-Sauveur-Le-Vicomte, a movement which traversed the base of the Cotentin Peninsula and carried the unit through

many badly battered Normandy villages. The Bailey bridges at Cotentin and Saint-Sauveur were underfire from German "88's" and under strong counterattack. One truck was knocked out by shell fragments, but there were no casualties.

The hospital set up the following day and opened at 1200 hours on 26 June. At this location, it supported the VII Corps drive to take the strategic port of Cherbourg. Heavy and medium artillery, as well as antiaircraft units, were set up in the adjoining field and drew considerable enemy fire, the shells in many instances landing in the hospital area. This stand, which was the medical personnel's first taste of combat, was perhaps the most exacting encountered by the hospital during all the continental operations.

When the X-ray department operated with the rest of the hospital for the first time under combat conditions, on 26 June 1944, it had its table of organization allotment of one clerk and three technicians. On the first day, 43 patients were examined and 102 radiographs made. In 7 days, the department made 848 radiographs.

It was immediately realized that, for the department to operate properly for 24 hours a day, more help was needed. Additional personnel were therefore trained during the next several weeks, until a total strength was reached of two clerks, two darkroom operators, seven technicians, and four litter bearers. With a staff of this size, the department was always able to keep ahead of the surgicial section after the first casualties received in each group had been examined. The technicians' duty hours were staggered, four being on duty during the day, when the heaviest influx of patients usually occurred, and the other three being on duty at night.

Carentan.—As soon as the liberation of Cherbourg had been accomplished, the hospital moved to its second location at Carentan, where it continued to support the VII Corps until a breakthrough was achieved at Saint-Lô.

Rennes.—The 35th Evacuation Hospital was then transferred to the Third U.S. Army and moved to Rennes, in Brittany. The movement was accomplished in a blackout. After the hospital had been closed in the evening, it was loaded on 2½-ton 6 by 6 trucks, which followed in convoy interspersed with tanks of the 4th and 6th Armored Divisions. At this time, the Third U.S. Army was pouring through the bottleneck at Avranches, under artillery fire and also under aerial bombardment. Strafing continued at intervals throughout the night.

The hospital arrived at Rennes at 0700 hours and went into operation at once in order to care for 600 recaptured Canadian and American prisoners of war, most of whom needed immediate medical care. It was the first Third U.S. Army hospital to go into operation on the Continent and later was the first to cross the Seine River. At Rennes, the main line of resistance, manned by the 8th U.S. Infantry Division, ran by the front door of the hospital, a

situation which gave rise to some interesting episodes, though the hospital, again, was spared any casualties.

The first casualties who presented themselves to the X-ray department were, as noted, recaptured prisoners of war. They had on casts and German metallic orthopedic devices of various types, and they presented some of the most challenging roentgenologic problems encountered during the war.

La Ferté Bernard.—When the 35th Evacuation Hospital moved to La Ferté Bernard, near XX Corps headquarters, the casualties were particularly light, and the X-ray department, as well as other departments, had an opportunity to improvise equipment (p. 449) which had been shown, during the first few weeks of operation, to be sorely needed.

On this move, as on several later ones, the plan was adopted of splitting the hospital and moving it in leapfrog fashion. At a given time, admission of casualties would be discontinued and half the hospital would move to the new location and set up for operation. The other half would finish processing the backlog of casualties in the old location, turn them over to a clearing-holding unit, and then proceed to the new location, usually about 8 to 12 hours after movement of the first half.

When this plan was adopted, the X-ray department would also split, leaving two technicians and one X-ray machine in the old location. These arrangements worked a considerable hardship on the advanced unit, which had to pack; load equipment; drive all night, frequently in a blackout; pitch tents; set up equipment; and immediately begin to process casualties, working for 12 hours or more if relief was slow in arriving.

Trying to keep ahead of the surgical load with only half the X-ray equipment and manpower was also difficult. It was not unusual for the chiefs of the surgical and X-ray sections to triage a patient, carry him to the X-ray department themselves, and then carry him on to the operating room because there were no litter bearers available. More than one wounded "GI" said later that, when he saw himself being carried around by a captain and a lieutenant colonel, he thought he was indeed "close to the Pearly Gates."

Verdun.—After leaving La Ferté Bernard, the 35th Evacuation Hospital moved through Richarville, on to Fontainebleau, where it was located on a ridge and where a quartermaster laundry company attached to it was knocked out by German fire.

In its move to the vicinity of Verdun, the hospital closely followed the 6th U.S. Armored Division. By this time, it had become hospital policy to set up as near the frontline as possible, to render the best possible close-in service to the combat troops. Often, this policy posed problems for the reconnaissance party, which was usually made up of the commanding officer or his executive officer, the chief of the surgical section, and the chief of the X-ray service. This party was frequently forced to reconnoiter uncleared territory in its probing for desirable hospital sites, 1 or 2 days before the

hospital eventually moved, and several times it had to wait for sites to be cleared.

The Verdun location was one of several in which there was only a small screen of combat patrols in front of the hospital. There were even fewer patrols between the left flank of the hospital and the enemy. Here, the current joke was that the 35th Evacuation Hospital was holding down the left flank of XX Corps and doing a roaring fine job with arm brassards, X-ray machines, and syringes. That the jest had considerable truth in it was evident on the occasions on which small groups of French civilians from surrounding towns would report to hospital headquarters that German panzer patrols were just down the road. These reports were always transmitted to XX Corps headquarters, which apparently took the situation promptly in hand, for no panzer units ever got as far as the hospital.

Drouville.—When the 35th Evacuation Hospital moved from the Verdun across the Moselle River to Drouville, it supported the XII Corps. Drouville proved to be a lively spot, with medium artillery dug in on the hills about the hospital and with a constant chatter of small arms fire in the distance. It was here that a sergeant, setting up the X-ray tent, needed a piece of rope or wire to fasten down a corner firmly and ordered a private to procure it for him. The private crossed the road, lifted a piece of wire, and asked if it would do. Said the sergeant, "Fine! Give me about 6 feet of it, and be quick." As the wirecutters snipped it, a colonel of the field artillery reared up with a now dead field phone at his ear, and glared at the poor private with the 6-foot section of telephone wire in his hand. Appropriate action was taken.

Nancy.—When instructions came at Drouville to all leading combat elements to halt and regroup, the 35th Evacuation Hospital moved back across the Moselle and set up at Nancy, where it remained from 27 September until 2 December 1944. During this period, the X-ray department made 8,711 radiographs.

Teting and Saint Avold.—On 2 December 1944, in bitterly cold weather, the hospital moved through the Maginot Line into a former German barracks building near Teting and Saint Avold. These barracks had been subjected to Allied aerial bombardment and artillery fire, in addition to small arms fire, and had been badly damaged. A platoon of engineers was assigned to the hospital, to aid in clearing out the rubble. So many German dead were found in the buildings and around the area by the cleanup detail that the location became known as "Graveyard Stand."

Luxembourg City.—Shortly after the German breakthrough and the beginning of the Battle of the Bulge, the 35th Evacuation Hospital received orders to proceed in two columns to Luxembourg City in time to set up and receive casualties by 1200 hours on 28 December. The two columns, accordingly, set out, under blackout conditions, and traveled by side and back-country roads generally parallel to the main highways, which were loaded with armored vehicles moving for the relief of the 101st Airborne Division at

Bastogne. Captain Lackey was in charge of one column and the chief of the surgical section, Col. Russell L. Malcolm, MC, was in charge of the other. In spite of their apprehension, the two officers met at 0600 hours, at a previously agreed on rallying point on the outskirts of Luxembourg City.

Here, orders were received for the hospital to set up in a long building which had previously been a religious center. By 1200 hours, when it became operational, an influx of patients began which was to continue until the end of February. The hospital was crowded with patients from the Battle of the Bulge, many of whom had to be hand-carried on litters up four narrow flights of stairs to the attic. Patients for whom there were no beds were cared for in the cellar or in the corridors.

In Luxembourg City, the darkroom tent was pitched indoors, in the room allocated to the X-ray department. During this stand, the X-ray backlog of patients frequently exceeded 250.

Helenenberg.—By 6 March 1945, the German counteroffensive had been stopped, and the Allies had launched a great new offensive. The 35th Evacuation Hospital moved to a large school building at Helenenberg, 20 miles north of Trier, and thus became the first of the Third U.S. Army hospitals to set up in Germany.

The hospital in this location was very far forward. In fact, contrary to the usual routine, the division clearing stations evacuated their patients forward to it. Small arms fire was frequently heard in the immediate vicinity, and large numbers of German troops surrendered to hospital personnel, including X-ray personnel.

During most of this stand, the X-ray backlog amounted to over 250 casualties. The backlog for the whole hospital was so large that the ambulance regulating post was set up in the hospital triage section, and casualties with minor wounds were sent back to hospitals in Luxembourg City and its environs, only casualties with wounds of the head, chest, and abdomen being admitted.

Two rooms were allocated to the X-ray department. The darkroom tent was pitched in one, and pictures were taken in the other. Army engineers knocked a hole through the 2-foot wall to serve for a pass box.

Darmstadt.—Shortly after the Third U.S. Army's assault crossing of the Rhine, the reconnaissance party of the 35th Evacuation Hospital was ordered to reconnoiter a suitable location for the hospital across the river. This party, which crossed over the famous pontoon bridge laid down by Army engineers, was the first evacuation hospital in the Third U.S. Army to cross the Rhine. The hospital set up at Darmstadt, after forcibly ejecting uniformed Nazi Party members from the buildings selected, which were the only two buildings in the city not gutted by fire bombs. The hospital was in operation long before any other troops, including military government troops, were quartered in the city.

Final moves.—On 12 April 1945, the 35th Evacuation Hospital moved to

Bad Salzungen near Hersfeld for a brief stand in tents. On 26 April, it set up at Grosschönbrunn near Amberg. The final move, after V–E Day, was to the Austrian border.

Facilities and Equipment

The greatest bottleneck in the rapid handling of patients at the 35th Evacuation Hospital was in the darkroom, in which the number of cassettes and hangers was insufficient. With larger numbers of both items, there could have been a great increase in the number of casualties handled.

Personnel of the X-ray department constructed wooden platforms to serve as mobile bases for the X-ray machines, which greatly enchanced their usefulness in rapidly processing seriously wounded casualties. Mobile tables were also made to be used with the litters and the mobile bases.

Wires were strung over the patients' beds in the shock and triage wards, so that, as soon as radiograms were processed, they could be hung directly over the beds. The immediate availability of the films facilitated triage of the patients and their selection for priority in surgery. Wires placed over the operating-room tables also made radiograms constantly available to the surgeons in the course of operation.

Never, during its entire operation in combat, did the X-ray department of the 35th Evacuation Hospital have replacements of any of its original equipment. It used the original generators, tubes, cables, and transformers from the beginning to the end of its service. All were considered satisfactory. In only one setup, at Nancy, was civilian power used. In all other locations, it was found too variable and unpredictable to be relied on. Servicing of the original generators, machines, and all other equipment was carried out by the department's own personnel, under the direction of the chief X-ray technician, S. Sgt. Rufus A. Wilz. The original equipment, as Captain Lackey repeatedly emphasized, was excellent, but it was the devoted work of the department personnel that kept it in good running order and made the whole X-ray operation as smooth and as uncomplicated as it was.

The average number of patients examined by X-ray personnel in a 24-hour period was about 40. When battle casualties were being received, the average daily workload was about 85. The maximum number of casualties handled in any single 24-hour period was 145.

Personnel

As has just been indicated, the tremendous output of work by the X-ray Department of the 35th Evacuation Hospital, coupled with the necessity for frequent long, rapid moves, is further evidence of the statement made many times throughout this volume that the radiologic history of World War II was really made by the X-ray technicians of the Army Medical Department.

Their work was a far more potent factor in department operations than was the type of equipment or the quantity of supplies.

The work of the chief X-ray technician of this hospital is proof of this statement. In addition to supervision of the X-ray equipment and construction of improvised equipment, he was responsible for the training of additional personnel under the extremely difficult conditions of full combat operation and tremendously heavy workloads. During this period, his routine responsibilities for the examination of seriously wounded casualties, plus his training duties, sometimes kept him on duty from 18 to 22 hours a day.

The table of organization of an X-ray department in an evacuation hospital had no position for a staff sergeant (p. 360). Sergeant Wilz received his rating by being put in charge of the surgical platoon, an arrangement that indicates the high esteem in which he was held by the officers of the hospital. He was awarded the Legion of Merit for exceptionally meritorious service against the enemy of the United States, during the period from 25 June to 25 December 1944, as noncommissioned officer in charge of the X-ray section of the 35th Evacuation Hospital. He was one of the few enlisted men in the Army to receive this decoration and, it is believed, was the only X-ray technician to receive it.

12TH EVACUATION HOSPITAL

The 12th Evacuation Hospital, a 750-bed semimobile unit, originated in the Lenox Hill Hospital, New York, N.Y., and received its training in the Tennessee maneuvers between 14 September and 10 November 1942 (table 12). The X-ray department was in charge of Maj. (later Lt. Col.) Frank Huber, MC, and Capt. Charles G. Huntington, MC.

The Tennessee maneuvers provided excellent training. Most of the X-ray work was of the station hospital type, but there were also many accident cases. Standard radiographic positioning techniques were employed whenever possible, and one discovery made at this time proved invaluable in combat experience; namely, that it is entirely feasible to examine a seriously injured patient from head to toe without moving him from the litter on which he has been placed originally.

Operations in the United Kingdom

The oversea experience of the 12th Evacuation Hospital began in the United Kingdom, continued through France and Luxembourg with the Third U.S. Army (as its only 750-bed evacuation hospital) and ended in Germany, in Frankfurt and Nürnberg. The United Kingdom period was also the first of many periods of inactivity for the hospital and the X-ray department.

East Anglia.—Between 29 April and 4 October 1943, the hospital set up and operated three Bolero (Nissen hut) hospitals, all in East Anglia, England.

TABLE 12.—*Condensed history of X-Ray Department, 12th Evacuation Hospital (750 beds), 1942–45*

Location and date	Mission	Equipment	Source of power	Housing	Personnel
14 Sept.–10 Nov. 1942, Tennessee maneuvers.	Evacuation and station hospital.	T/E	2.5 kw. T/E generator plus community line 110 kv.	Single-ward tent, dirt floor.	1 officer, 4 enlisted men, single 12-hour shift.
29 Apr.–4 Oct. 1943, East Anglia, England (Redgrave Park, Whitecourt Park, Morley Hall).	Evacuation and station hospital. First battle casualties (Air Corps).	Same, plus British mobile unit, plus U.S. tilt table and energy unit.	2.5 kw. generator, T/E (as standby), mainly community line 110 kv.	Nissen huts, concrete floor.	Same at each hospital.
20 Oct. 1943–25 Mar. 1944, Carmarthen, Wales.	Evacuation and station hospital. Experimental project (tents to huts).	T/E plus British mobile unit and table.	2.5 kw. T/E generator, then 110 kv. community line.	Single-ward tent, fairly near receiving and operating-room tents.	2 officers, 6 enlisted men, single shift.
17 May–7 July 1944, Moreton, England.	Transit hospital. Invasion casualties.	T/E	2.5 kw. T/E gas generator plus line current plus 3 kw. gas generator.	do	2 officers, 6 enlisted men, double shift.
23–29 Aug. 1944, Bonneval, France.	Transit hospital.	do	2.5 kw. plus kw. gas generators.	2 ward tents connected end-to-end with receiving and operating-room tents.	Do.
7–28 Sept. 1944, Vadelaincourt, France.	do	do	2.5 kw. plus 3 kw. gas generators.	2 ward tents connected side-to-side with receiving and operating room tents.	Do.

TABLE 12.—*Condensed history of X-Ray Department, 12th Evacuation Hospital (750 beds), 1942–45*—Continued

Location and date	Mission	Equipment	Source of power	Housing	Personnel
10 Oct. 1944–7 Jan. 1945, Nancy, France.	Evacuation and station hospital.	T/E plus French tilt Bucky table and energy unit. Hospital darkroom.	Line current	French Army hospital, next to operating room and near receiving ward.	Do.
15 Jan.–16 Mar. 1945, Luxembourg.	Evacuation hospital.	T/E	Two 15-amp. Diesel generators (above T/E), plus community line.	Luxembourg Army barracks, between receiving ward and operating room.	Do.
7 April–15 May 1945, Frankfurt, Germany.	Evacuation and station hospital.	do	Two 30-kw. Diesel generators.	2 ward tents connected side-to-side with receiving, shock, and operating-room tents.	Do.

near the airfields. Practically all the work was of the station hospital type except for a few battle casualties from the Air Forces.

In East Anglia, the X-ray department of the 12th Evacuation Hospital first made contact with Lt. Col. (later Col.) Kenneth D. A. Allen, MC, Senior Consultant in Radiology. His inspection trips in the field were always most welcome, and with the cordial cooperation of the Central X-ray Supply Depot (M–400, p. 401), he was able to solve many problems.

Carmarthen.—On 20 October 1943, the 12th Evacuation Hospital moved to Carmarthen, in Wales, to carry out an experimental project: the operation of a hospital in tents, with gradual transition to Nissen huts as the cooperating Corps of Engineers completed these facilities. The operation furnished excellent training and was most successful, but nothing like it eventuated on the Continent because of the rapid tempo of the advance. The early experience, in tents, was rugged, and when the unit was about to reap the rewards of the experience and move into huts, it was replaced by a station hospital and was moved to another location.

Moreton.—On 17 May 1944, the hospital occupied a site at Moreton, near Weymouth, England, on the near shore. The designation of the installation as a transit hospital implied that it would treat casualties evacuated from the Continent during the invasion. Once the invasion began, the X-ray department inaugurated round-the-clock operations of double 12-hour shifts.

Continental Operations

Bonneval.—The 12th Evacuation Hospital arrived on Utah Beach on the far shore by troopship at the end of July 1944. Several weeks were spent in bivouac, marking time, until the Avranches-Saint-Lô breakthrough. Thereafter, it was a question of keeping up with the rapidly advancing Third U.S. Army.

The first operation of the 12th Evacuation Hospital on the Continent was at Bonneval, below Chartres, 23–29 August 1944. With only 6 hours' notice after its arrival, it began to receive large numbers of patients, and the value of its long training phases began to pay off in actual field operation. The practice just mentioned of making complete examinations of severely injured patients without moving them from the litters on which they were brought into the hospital and without removing their clothing proved extremely useful. It lessened strain on the patients and helped to prevent serious backlogs in the X-ray department when casualties were heavy.

Vadelaincourt.—Because of the rapid advances of the fighting forces, the hospital was not set up again until 7 September 1944, at Vadelaincourt (fig. 161) near Verdun, where it functioned in a completely satisfactory manner until 28 September 1944.

By the time the move to Vadelaincourt was made, loading, transportation, and setup had become rapid, systematic, and efficient. Then and later, trucks from a central motor pool were supplied for each hospital, usually in units of 30 to 35, which shuttled back and forth from the original to the new location until the move was completed. X-ray equipment and supplies were usually transported in a 2½-ton truck and trailer, which had space for the transportation of some personnel also.

The setup here was highly efficient because of lessons learned earlier on the Continent. At the first location, the receiving, shock, X-ray, and operating-room tents were rather widely dispersed. At Vadelaincourt, they were pitched together, in the manner of a branching tree, with the receiving tent forming the trunk (fig. 161). The concept of having the major services close together and under connecting canvas was brought from the North African theater by the medical units that had functioned there and that had found that the increased compactness of this arrangement resulted in a great saving of time and effort.

At Vadelaincourt, as later, water requirements for X-ray service in the field, where running water was generally unavailable, were a constant con-

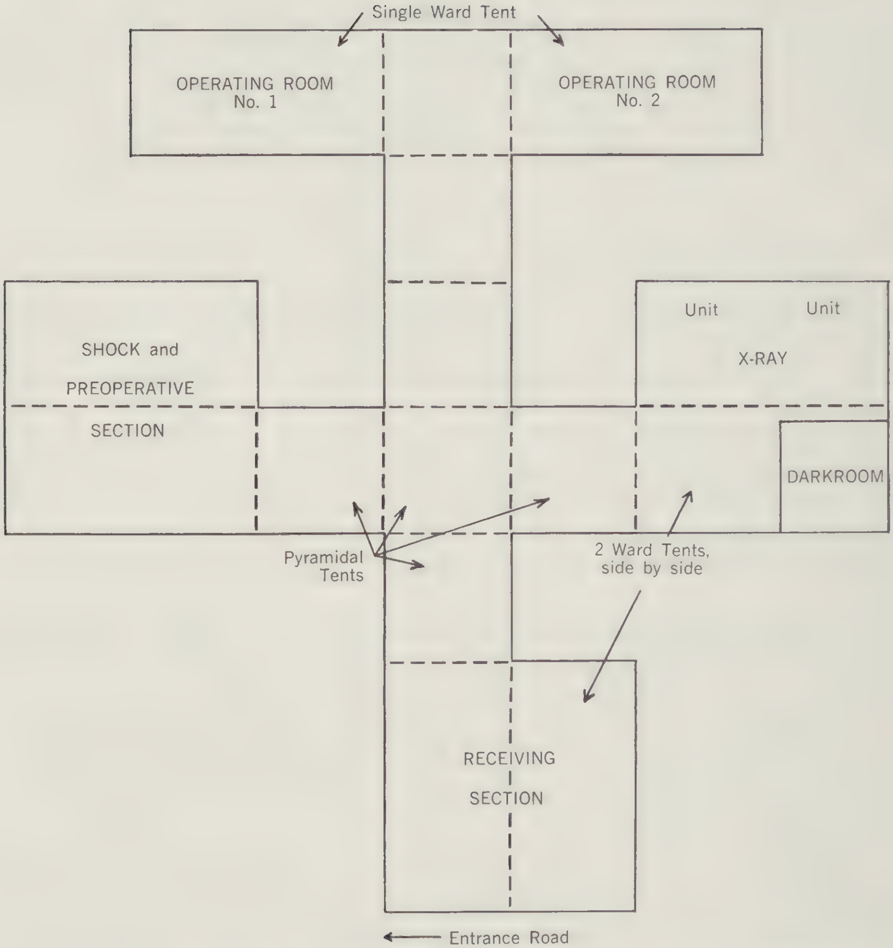

FIGURE 161.—Diagram, showing arrangement of evacuation hospital under canvas cover and flow of traffic which this arrangement permits. 12th Evacuation Hospital at Vadelaincourt, France, September 1944.

cern. It was found that, by reducing needs to a minimum, a supply of 50 gallons was adequate for even the busiest day's work. Such economy facilitated the functioning of the department in many situations in which operations otherwise would have been almost impossible.

Nancy.—The next operation began on 10 October 1944, in Nancy, where the 12th Evacuation Hospital was located in a large French military hospital which had been occupied by the Germans.

The space allotted to the X-ray department here was rather small, but the darkroom was most acceptable. Most of the work was done with table of equipment items, although there were available also a ponderous French tilt Bucky table and an energy unit.

Large numbers of casualties were brought to the 12th Evacuation Hospital at Nancy whenever a push occurred. On occasion, the backlog of patients awaiting X-ray examination reached 200. The previous training and experience of the departmental personnel proved most useful in facilitating rapid elimination of the bottleneck. It was also helpful to have X-ray and surgery in the same wing, with the receiving section in the adjacent tent. Casualties requiring emergency surgery received prompt attention after triage in the receiving and shock wards.

At Nancy, as elsewhere, procurement of litter bearers was a serious problem. When the patient load was heavy, especially if the hospital was in a building with more than one floor, detachments had to be assigned for this purpose from a central pool.

Luxembourg City.—The busy Nancy operation ended on 7 January 1945, when the 12th Evacuation Hospital was replaced by the 2d General Hospital and was moved to Luxembourg City. Here, after some difficulty, a site for the hospital was found in the Caserne des Volontaires, the barracks of the Luxembourg Army. The main building was built on the side of a cliff, the top floor being at the same level as the top of the cliff, and the main portion of the city. The receiving, shock, X-ray, and operating-room departments occupied the top floor, which had previously been used as an attic. All hands participated in the cleaning necessary before the building could be occupied.

The hospital opened at this site on 15 January 1945 and functioned most efficiently, chiefly during the period of the reduction of the Bulge, until 16 March 1945.

Frankfurt.—The final site occupied by the 12th Evacuation Hospital was the grounds of the Municipal Sport Stadium, on the outskirts of Frankfurt, beginning on 7 April 1945. The setup for field operations, which even included running water, was unusually luxurious. The workload was something of a letdown, after the intensity of previous operations on the Continent, but there was enough work to keep all personnel comfortably busy.

The active phase of the hospital operation ended on 15 May 1945, a week after V–E Day.

Professional Considerations

By the end of hostilities, the X-ray department of the 12th Evacuation Hospital, in its separate locations (table 12), had made 411 fluoroscopic and 26,428 radiographic examinations of 22,182 patients, for whom it had used 37,681 films.

During the Frankfurt operation of the hospital, a therapy center was set up, in response to the need for it in forward areas. The administration of superficial therapy had been a considerable problem. Because of lack of facilities for it in the Army area, men with minor skin diseases requiring that modality had had to be sent to Paris from forward areas in France, Luxembourg, and Germany. This plan entailed a total loss of manpower and added

to transportation difficulties. The operation of a therapy center at Frankfurt seemed, theoretically, an excellent solution, but it proved impractical because of inadequacies of space, power, apparatus, and protection (p. 488).

Equipment

The X-ray department of the 12th Evacuation Hospital began operations with table of equipment which included a film chest, a film-loading bin, a 2.5-kw. gasoline generator, a portable grid, a 30-ma. X-ray machine, an X-ray table, and a darkroom tent. Driers and film-processing units were usually, though not always, provided.

In addition to this equipment, accessory or substitute items were found in some of the installations occupied on the Continent. Because of improvisations, X-ray services were never lacking at any of the oversea locations, but the need for the improvisations indicated the need for additions to the table of equipment. The deficiencies included vertical cassette holders, serial spot-pressure devices for barium meal studies, pass boxes for darkrooms, wooden trolley rails for mobile X-ray units used on rough terrain, protective lead or lead rubber shields, and identifying photographic film markers.

The criteria of versatility, portability, and practicability were generally met in the equipment provided, with one exception: The localizing device for foreign bodies was not found satisfactory and was seldom used.

Plain films in two projections, at right angles to each other, were found quite satisfactory throughout the war; only 411 fluoroscopic examinations of all kinds were made by the X-ray department of the 12th Evacuation Hospital from the beginning of hostilities in the European theater until their end.

Special Assignments

By the end of hostilities, Colonel Huber, in addition to his duties as head of the X-ray department of the 12th Evacuation Hospital, also performed a number of hospital functions. He variously served as fire marshal; investigating, billeting, executive, and electric power allotment officer; and court-martial member.

Colonel Huber also carried out two special assignments. One of them, in connection with recaptured radium, is described elsewhere (p. 399). The other had to do with protection against radiation, about which there was some concern in the Office of the Surgeon, Third U.S. Army. Late in 1944, during the Battle of the Bulge, Colonel Huber was assigned to inspect some 30 X-ray installations, his duties at the 12th Evacuation Hospital being assumed during his absence by his associate, Captain Huntington. Colonel Huber found that, with few exceptions, practical protection measures, based on good commonsense, were in effect at all installations. In the forward areas, there was initially some skepticism concerning his mission because of the apparent incon-

gruity of such long-range protective measures when the dangers of enemy action were so imminent. In each instance, a few words about potential leukemia promptly changed the point of view, cleared the air, and corrected unsatisfactory practices.

CHAPTER XVII

Diagnostic Considerations in Military Radiology

Kenneth D. A. Allen, M.D.

GENERAL CONSIDERATIONS

Any contribution made toward diagnostic roentgenology in the European Theater of Operations, U.S. Army, in World War II was chiefly accomplished by indicating the direction in which further postwar studies should be conducted. Few new diagnostic principles were elucidated in the European theater. Improvisations in equipment were frequent and ingenious (p. 379), but little really new was developed in regard to diagnosis.

There were three reasons why investigations that were begun could not be carried to a final conclusion: (1) The necessity for speed in the examination of battle casualties when they were hospitalized in large numbers; (2) the paucity of material in periods when stress was not a factor and there was relatively ample time; and (3) a continuing need for economy in the use of films. Most early studies on severe trauma of the chest and abdomen, to use a single illustration, were made in field hospitals, in which there were no radiologists qualified to undertake research and no special equipment for it. The abrupt ending of hostilities in the theater, on 8 May 1945, and the upheaval of redeployment precluded the completion of articles and the collection of statistics which had been begun.

All of this material, of course, was not lost. A considerable amount was published during and after the war or found its way into the medical literature through the editorial boards of the theater and the Office of The Surgeon General. Furthermore, in spite of the handicaps just listed, diagnostic radiology in the European theater had more than its immediate value, since the total experience, combined with the amount of investigative work possible, pointed toward new ideas to be developed in the postwar period or indicated additional avenues of approach to old subjects.

GENERAL PRINCIPLES OF FOREIGN BODY LOCALIZATION

In March 1943, the Senior Consultant in Radiology began to direct the attention of radiologists and technicians to the subject of localization of foreign bodies. He suggested, in his visits to all hospitals, that they become

thoroughly familiar with the use of field X-ray tables (items No. 96145 and No. 96215) for the localization of foreign bodies elsewhere than in the eye.

Equipment and Technique

The issue radiographic tables provided adequate equipment for the fluoroscopic localization of foreign bodies elsewhere than in the eye, but after D-day, they were not used very often, for the practical reason that most radiologists as well as most surgeons preferred anteroposterior and lateral radiographs, which provided a permanent record to be carried into the operating room. Fluoroscopic localization of foreign bodies in the lower pelvis continued to be necessary, especially when only low-power machines were available, but some radiologists preferred anteroposterior and lateral films of this area even if the department was equipped with high-power machines.

The use of radiography rather than fluoroscopy had been stressed in directives, and the final figures showed that the injunctions had been heeded: Between 1 January 1943 and 31 December 1944, 291 quarterly reports from general hospitals recorded only 6,357 localizations of foreign bodies by fluoroscopy, and in many of these cases, anteroposterior and lateral views were also made either before or after the fluoroscopic localization. As a matter of fact, only three or four hospitals did any material amount of fluoroscopy, and the radiologist of one of them, as related elsewhere (p. 338), had to be evacuated to the Zone of Interior because of anemia.

So far as is known, the biplane marker and reorientation device (Item No. 96191) provided were used completely only once in the European theater at the 30th General Hospital in Normandy. By this means, a foreign body which had defied other methods of localization was successfully removed. The 90th General Hospital frequently used the X-ray portion of the device, but not the removable portion, in the operating room. The device was very accurate, but it did not lend itself to wartime requirements.

Captured German equipment.—The end of the war brought the opportunity to study German equipment in use in civilian practice, as well as experimental models of new equipment being tested in universities. The apparatus, invented by Prof. Albert Hasselwander (fig. 162) at the University of Erlangen, Germany, was of particular interest because it localized the foreign body by utilizing cross sections of the part in which the object was located. A precision stereoscope, of the type used for measuring pelvic diameters, and semitransparent mirrors allowed the stereoscopic image to be cast in space against a black background. A marker, consisting of a small electric bulb mounted on a parallelogram, followed the contours of the object as it appeared in space at the desired level. By means of a pencil mounted at the bottom of the strut which carried the light, a cross section of the part and the location of the foreign body could be drawn on a sheet of paper.

This instrument required excellent stereoscopic perception to achieve

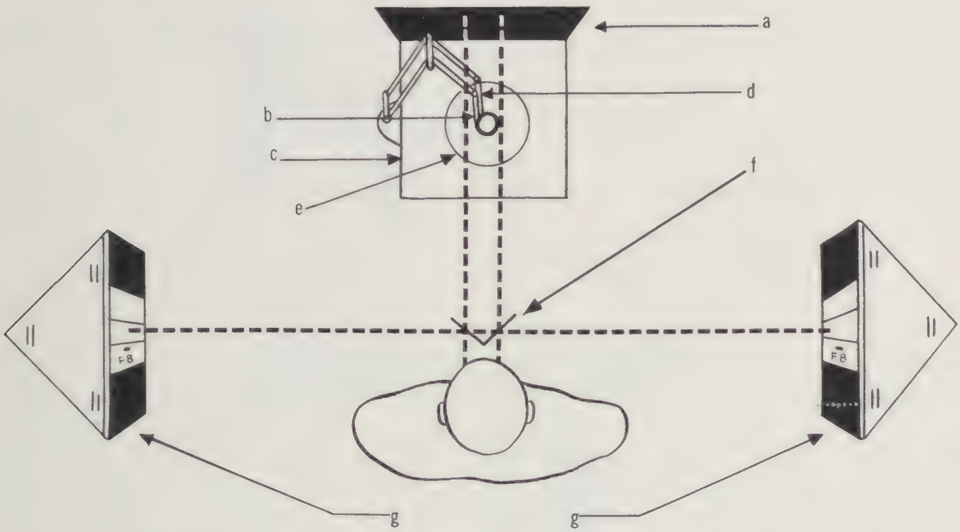

FIGURE 162.—Hasselwander technique of stereoscopic localization of foreign bodies by means of cross-sectional drawings: Black screen (a), pencil (b), paper (c), light marker (d), drawing of cross section, with foreign body (e), semitransparent mirrors (f), and illuminators (g).

accurate results. Its chief advantage was that, by consultation of anatomic cross section charts and comparison of the charts with the drawings made by the instrument, a good idea was gained of the location of the foreign body in relation to muscular and skeletal structures.

A captured German Boloskop for the localization of foreign bodies (fig. 163) was found to have a number of parts missing. These were reconstructed by Lt. Col. Alfred C. Ledoux, MC, Chief, Radiology, 108th General Hospital, Paris, France, and the apparatus was adapted to use with the U.S. Army field unit by the triangulation method (*1*). This instrument proved to be the best localizer for foreign bodies available in fixed hospitals.

The kymographs to be described (p. 463) and the German Boloskop, adapted to U.S. use, were the only pieces of equipment developed during the war which involved any new principles in the localization of foreign bodies.

Other methods.—By one technique, a perpendicular, pencil-size X-ray beam from any undertable fluoroscope was directed through the foreign body to the screen, to guide the insertion of a needle directly in the beam until it struck the foreign body. The needle was then left in place for the surgeon's guidance. This method, which apparently was not used in World War I, was used to some extent in civilian life before the war. It was simple and proved effective in the few selected cases in which it was used in World War II. It was particularly successful in the hands of Lt. Col. Robert P. Ball, MC, radiologist at the 2d General Hospital.

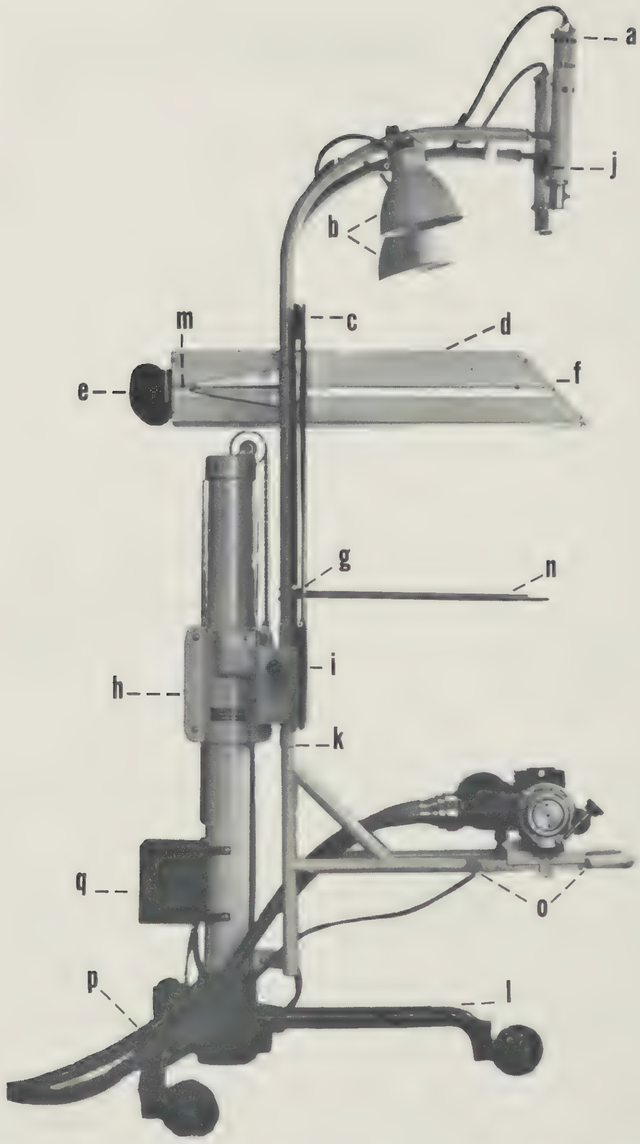

FIGURE 163.—Captured German Boloskop for localization of intraocular foreign bodies: Tubular localizing lights (a), general purpose lights (100 watts) (b), lead rubber protective screen (c), fluoroscopic tunnel (d), padded eyepiece for observation of fluoroscopic screen (e), fluoroscopic screen (f), hole for insertion of removable rod (part n) (g), casting to attach tube, screen, and lights to upright mobile stand (h), bicycle grip to shift X-ray tube (i), adjusting screw to control size of aperture (j), tubular frame to support tube, screen, and lights (k), mobile stand (l), lock to limit travel of fluoroscopic tunnel (m), metal rod to check lights, target, and screen positions (n), stops to limit travel of tube (o), lock to limit travel (p), and stepdown transformer, providing 6 volts for lights (part a) (q).

All techniques and apparatus suggested for foreign body localization—many such suggestions were made to the Senior Consultant in Radiology in the course of the war—were either based on the triangulation method (*2*) or on the formula of Buguet and Gascard (*3*). Both methods had been devised within 2 years after the discovery of X-rays. The X-ray field tables (items No. 96145 and No. 96215), which employed the triangulation principle, were entirely satisfactory for localization purposes in both forward and rear areas.

FOREIGN BODIES IN AND ABOUT THE HEART

During the late summer and fall of 1944, considerable attention was given to the localization of foreign bodies in and near the heart. The subject was emphasized by the radiologic consultants at meetings, during visits to hospitals, and in directives after several foreign bodies within the heart had been missed at one hospital and were later identified at another.

A routine technical investigation, instigated by a theater circular letter (*4*), was responsible for revealing several previously undetected foreign bodies in or near the heart and emphasized the importance of a diligent search for them whenever a penetrating wound of the chest was encountered.

Kymography

Localization of foreign bodies in and near the heart required an extremely careful technique, which included delicate fluoroscopy, Bucky posteroanterior and lateral films, and posteroanterior overexposed ($\frac{1}{10}$ second or less) films. Even with all of these methods, the exact anatomic localization which the roentgenologist suspected could be verified only at operation. The requirements of cardiac surgery imposed exacting demands on him, and kymography helped to solve his problem.

Localization of foreign bodies within the cardiac chambers, in the cardiac wall, or just outside of the heart was accomplished at the 48th General Hospital by kymographs improvised by Maj. (later Lt. Col.) Cesare Gianturco, MC, and at the 160th General Hospital by Maj. Arthur H. Joistad, Jr., MC (*5*).

By this technique, subpericardial and pericardial foreign bodies lodged opposite a great vessel or a heart muscle showed transmitted pulsations characteristic of these anatomic structures. If they were within the cardiac chambers, they showed dissociated motion. The bizarre movement of intracardiac foreign bodies seen on fluoroscopy and the frequent association of pericardial effusion described in the literature were not observed.

The kymograph devised by Major Gianturco (fig. 164) consisted of the following parts:

1. An upright wooden tunnel, in which a 10- by 12-inch cassette could slide.
2. Lubricating oil in a 2-cc. syringe, which furnished enough resistance to check the

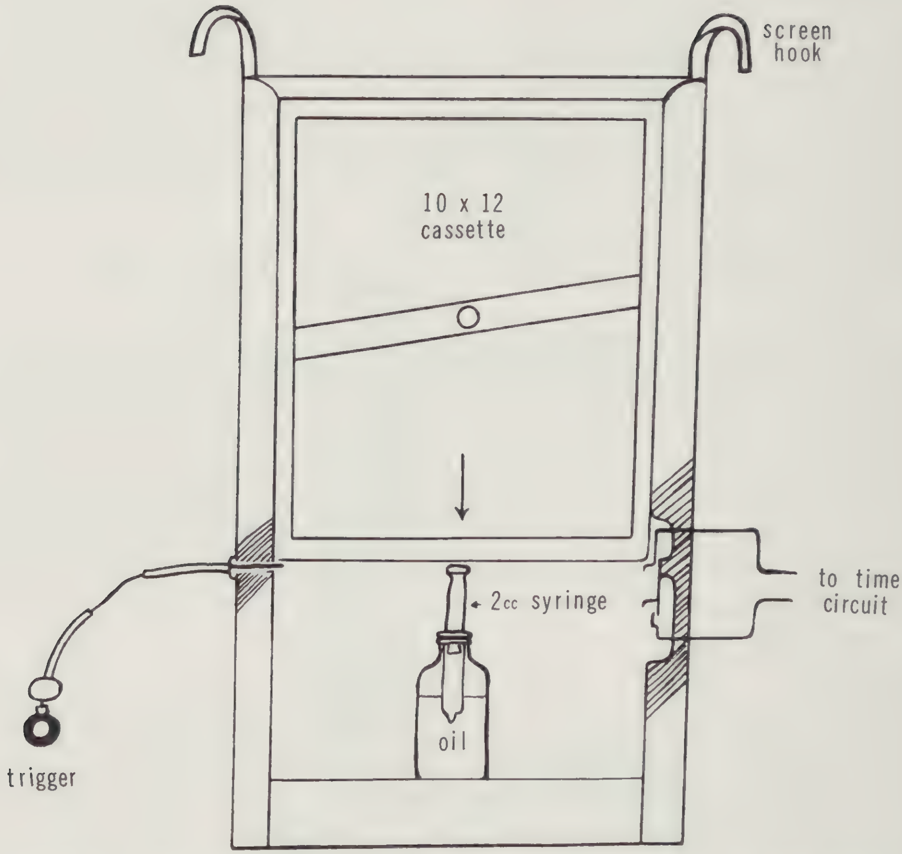

FIGURE 164.—Cardiokymograph devised at 48th General Hospital by Maj. Cesare Gianturco, MC, shown from rear.

speed of the fall of the cassette. The speed of the kymograph could be controlled by altering the viscosity of the oil.

3. A grid of two lead strips, each three-fourths of an inch wide, placed side by side between two pieces of plywood, with a slot one-sixteenth of an inch wide between the lead strips.

4. Appropriate switches to control the X-ray exposure.

5. A trigger to hold the cassette in place until the operator was ready to make the exposure. When the trigger was released, the cassette began to move.

The apparatus, without the cassette, was hung in front of the fluoroscopic screen. The foreign body was centered fluoroscopically in one of the slots. The cassette was then inserted and the trigger released, which permitted the cassette to begin its fall. A set of contacts on the back of the frame energized the timer circuit, so that the exposure continued until the cassette had dropped the distance of one lead strip.

The kymograph devised by Major Joistad, which was of the moving

film type, was constructed entirely of items of available electrical and mechanical equipment:

A stationary grid, 14 by 20 cm., was made by gluing to a durable Bakelite panel two strips of lead rubber, each 12 mm. wide, 2 mm. thick, and 14 cm. long, with a 0.4-mm. space between them. The completed grid was bolted against a piece of ¼-inch plywood. Tests at 80 kv. and 150 ma. seconds had shown that the lead rubber provided sufficient X-ray stoppage for the purpose.

The mechanism for moving the 14- by 17-inch cassette incorporated the principle of hydraulic control. Clamps secured the cassette to a support that moved freely in guiding rods along each side. A sturdy arm attached to the support articulated with a plunger in an oil-filled cylinder. The outflow of oil was regulated by an adjustable petcock; the speed at which the entire cassette-supporting assembly moved was thus controlled. To assure smooth movement, strong springs were attached to the moving assembly, which, once it was cocked, was locked into place by a special latch and was released automatically when the X-ray exposure switch was pressed.

Built into the arm of the cassette-supporting assembly were electrical contact points that controlled the exposure time of the X-ray machine. The exposure did not start until the film was well in motion, and it continued only long enough for the film to travel 12 millimeters. The exposure, which was entirely automatic, was synchronized with that of the X-ray timer. The entire film-moving assembly and the electrical contact points were housed in a specially designed casing, and the grid just described was hinged to one side of the housing.

The entire kymograph was hung on a standard cassette changer, an arrangement which allowed it to be raised and lowered to accommodate the needs of different patients. A special double-throw switch changed the normal X-ray timer circuit to the kymograph circuit.

When a kymograph was to be taken, a cassette was inserted and the patient positioned. The X-ray tube was centered, the proper factors selected, and the exposure made in the usual way. Pressure on the exposure switch of the X-ray machine released the film-moving assembly. If the assembly jammed or otherwise failed during the exposure, the regular X-ray timer terminated it within the limits of patient and tube safety factors.

The location of 134 foreign bodies in and around the heart encountered at the 160th General Hospital (*6*) was determined by routine radiography, supplemented by kymographic studies, to be as follows:

Pericardial	26
Pulmonary with some pericardial involvement	17
Intracardiac	13
On or in walls of great vessels	35
Intravascular (3 embolic)	7
Pulmonary with some intravascular involvement	17
Mediastinal, not directly on great vessels	19

The use of the kymograph at the 160th General Hospital showed remarkable promise. Dr. A. E. Barclay, Chief of Radiologic Research at the Nuffield Institute, Oxford, England, made cinematographic studies of heart movements in his own hospital. In his kindly opinion, the demonstration of certain heart movements not hitherto depicted might well become one of the outstanding radiologic contributions of the war.

The successful localization of foreign bodies in and around the heart by kymography is illustrated in figure 165.

INTRAOCULAR FOREIGN BODIES

For eye work, the Senior Consultants in Ophthalmology and Radiology so coordinated their personnel assignments that radiologists proficient in localization of intraocular foreign bodies and other eye work were placed in hospitals in which capable ophthalmologists were on duty and in which there was adequate apparatus for the localization and removal of these objects.

No new principles were involved in the localization of foreign bodies in the eye in the European theater. The problem was chiefly to train radiologists in the use of available equipment under wartime conditions. Orientation was accomplished by meetings and personal instruction, supplemented by an article on the subject prepared by the Senior Consultant in Radiology and published in the *ETOUSA Journal of Ophthalmology* in September 1943 (*7*).

This article, which was concerned only with radiologic techniques of localization, contained the following information:

All known methods of localization of intraocular foreign bodies can be classified into three categories, all calculations being based on an eye of average size and shape:

1. Plain radiography without accessory apparatus, as a basis of comparison with other techniques. This method includes routine posteroanterior and lateral roentgenograms and oblique bone-free roentgenograms.
2. X-ray tube-shifting methods, including plain stereoscopic studies; stereoscopic studies with air in Tenon's capsule; and studies with special apparatus. The latter studies include the use of the cork wire model; the modified or improved Sweet apparatus and techniques; and the Pfeiffer or McGrigor apparatus and technique.
3. Stationary-tube moving-eyeball method.

In this discussion, great emphasis was placed upon the reliability and accuracy of the Sweet method (*8*), first described in 1909.

Since extreme accuracy and attention to detail are of great importance in all methods, both radiography and interpretation must be carried out by a radiologist, not by a radiographic technician. Patient cooperation is essential. Two complete localizations with identical results should be accomplished before the results are reported to the surgeon. No method is absolutely accurate, especially if the foreign body is not in the principal horizontal or vertical section of the eye. Difficulty may also be encountered when it is close to the periphery. In the latter instance, the object may appear to be within the globe in all three projections and still, because of the shape of the eye, be just outside. The only method that takes these factors into consideration is the McGrigor technique (*9*).

There are several methods of determining whether the foreign body is extraocular:

1. The meridianal method of Goalwin (*10*).

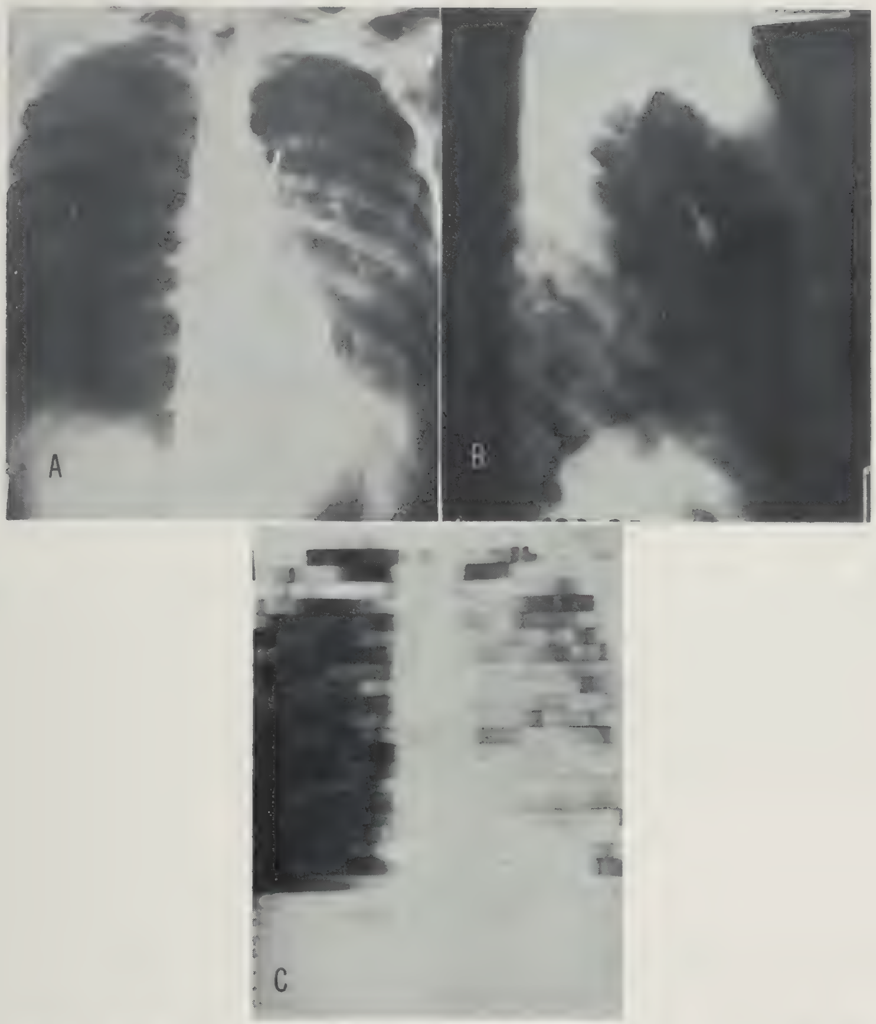

FIGURE 165.—Localization of foreign body in upper thorax of patient who had also sustained fractures of several ribs and had developed a hemothorax. In this case, it was impossible to separate the transmitted pulsations of the aorta from other movements of the foreign body (160th General Hospital). A. Anteroposterior depiction. B. Lateral depiction. C. Demonstration of foreign body immediately adjacent to aorta but within pulmonary substance. In spite of the hemothorax at the left base, the amplitude of pulsations along the left border of the heart were seen to be of good quality. The pulsations transmitted from the aorta to the foreign body had the characteristic waveform of aortic pulsations, which were normal except for the knob; here their weakness suggested possible associated injury to the aortic wall.

2. The square root rule.
3. Separate localizations of each end of an object longer than 3 millimeters.
4. Modifications of method 3.

Better detail can be secured by utilizing cardboard holders in preference to screens for the preliminary radiographic studies employed to establish the presence of a foreign body in the eye.

Three views are necessary; namely, routine posteroanterior, lateral, and bone-free oblique.

By the Vogt technique (*11*, *12*), small films in lightproof paper are held against the conjunctival sac. By another technique, the exposure is made with the affected side toward the cardboard holder, with the face rotated slightly upward and the cone sufficiently inclined to pass the central ray along the base of the nasal bone toward the outer wall of the orbit. This technique reveals glass and gravel as well as metal in the anterior portion of the eye.

Among the other points discussed in this article were the following:

1. Experience and skill are of the greatest value in successful localization of intraocular foreign bodies. One radiologist at a general hospital utilized slack periods for repeated localizations of foreign bodies in wax eyeballs. Colonel Allen urged all radiologists to follow this plan and practice ocular localization with wax eye models containing metallic foreign bodies in skulls or in wooden blocks.
2. Visualization is possible only when foreign bodies have a specific gravity or density considerably greater than that of soft tissue.
3. The best results are achieved with relatively long target-film distance, with the smallest possible cone; a hole cut in a lead diaphragm suffices for such a cone. Neither the grid nor the Bucky diaphragm should be used.
4. The head should always be completely immobilized before radiography is carried out.

PNEUMOARTHROGRAPHY

Pneumoarthrography was employed at some hospitals in the European theater in borderline instances of joint involvement, particularly involvement of the knee, in which a clear-cut clinical diagnosis could not be made. In the 80 cases of foreign bodies or loose cartilage examined at the 1st General Hospital by this method by the radiologist, Capt. (later Lt. Col.) Vincent M. Whelan, MC, the surgeons agreed with him that this was a safe and reliable technique (figs. 166–168).

This same method was used at the 297th General Hospital in 247 cases by Maj. (later Lt. Col.) Hampar Kelikian, MC, and Capt. (later Lt. Col.) E. Kenneth Lewis, MC (*13*). The method was used, in a descending order of frequency, on the knee, the ankle, the elbow, and the shoulder joint. Neither infection of the joint nor air embolism followed in any instance. The information gained enriched the understanding of the anatomy of the joints and of pathologic processes in them. A great deal of knowledge was also gained concerning the contour of the joint cavity, its capacity, its contents, and its communications. Because these special studies were of great value

FIGURE 166.—Pneumoarthrography of knee. A. Posteroanterior projection, showing normal medial meniscus. Note clear delineation of triangular meniscus by oxygen above and below it. B. Posteroanterior projection, showing obvious tear in medial meniscus. C. Surgically removed damaged medial meniscus.

in localizing both metallic foreign bodies and osseocartilaginous bodies, particularly with reference to their intracapsular or extracapsular location, pneumoarthrography was of great help to surgeons in planning and carrying out purposeful surgical approaches for the removal of these objects.

The following description of the technique employed at the 297th General Hospital was supplied by Captain Lewis:

Immediately after the air is injected into the joint, the patient is radiographed before any considerable escape or leakage of the air. If the pneumoarthrogram is of the knee, which is the most common joint to be examined, 100 cc. of air is injected. The radiographs are made either at the table, where air is introduced, or if the patient is to be moved, he is not to bear weight until after radiographs have been exposed. The radiographs needed for the knee examination are:

(1) *Anteroposterior*, with the patient supine and the knee slightly flexed about 5 degrees. The central ray is centered to the tibial plateau and directed perpendicular to the longitudinal plane of the tibia.

(2) *Lateral*, with patient supine (dorsal decubitus) and central ray directed through the middle of the knee joint.

(3) *A second lateral* with patient prone and knee moderately flexed to allow air to be distributed to dorsal pouches of knee joint and visualize the same.

(4) *Posteroanterior*. Knee flexed with patient in kneeling position. The central ray is directed through the fold of the popliteal space, and perpendicular to the longitudinal plane of the tibia.

Upright film studies used to supplement the foregoing were useful in demonstrating fluid levels and displacement of opaque foreign bodies.

RADIOGRAPHY OF THE ABDOMEN

At the 297th General Hospital, special studies with artificial pneumoperitoneum proved of considerable value in localizing metallic foreign bodies in relation to the diaphragm, liver, and spleen (fig. 169). These studies also

FIGURE 167.—Pneumoarthrogram of knee taken in lateral upright position. Note fluid level in the joint, with no foreign body.

proved useful in the demonstration of intra-abdominal masses, abscesses, and peritoneal adhesions that are the occasional sequelae of abdominal and chest wounds. The examination included fluoroscopy and radiography, as follows:

1. Lateral transabdominal view, in dorsal decubitus.
2. Right anteroposterior view, in lateral decubitus.
3. Left anteroposterior view, in lateral decubitus.
4. Lateral transabdominal view, in ventral decubitus.
5. Anteroposterior view, with the patient erect.

All radiographs were made with the Bucky-Potter diaphragm, using the shortest possible exposure time.

Radiographs of the abdomen that demonstrated the intestinal gas pattern were found useful in two special kinds of injury:

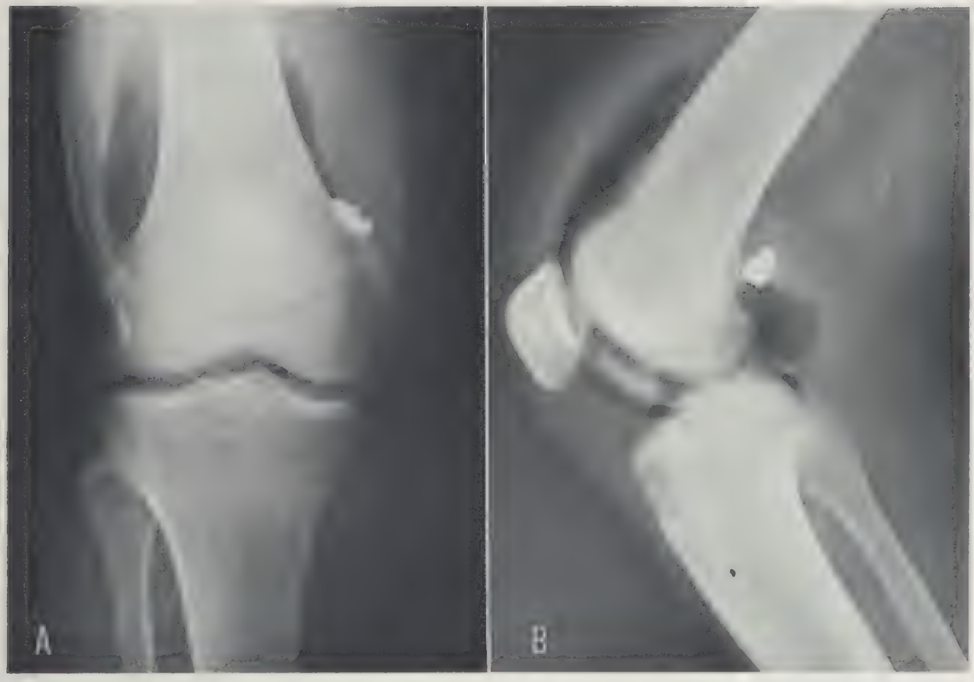

FIGURE 168.—Anteroposterior pneumoarthrogram of knee, showing extrasynovial shell fragments. A. Anteroposterior projection. B. Lateral projection.

1. Perforating wounds, in which the metallic foreign body was no longer present to guide the surgeon.

2. Penetrating wounds caused by nonopaque foreign bodies, such as wood bullets.

This information was especially useful in field hospitals to which nontransportable casualties had been admitted to be made transportable. A loop of small bowel or colon would often be found distended proximal to the site of injury, with little or no gas distal to the injury area. The injury to the tissue, not the presence of a foreign body (fig. 170), explained the failure of the gas to pass the point of damage.

Studies in forward hospitals of cases in which anteroposterior radiographs of the abdomen showed traumatic pneumoperitoneum revealed that the source of free air was not always a perforation of the intestine. In many such cases, the presence of air was to be explained by a rupture of the lung through the diaphragm, as in blast injury, or was simply air which had entered by way of the wound.

Radiography was also useful in other varieties of abdominal trauma (figs. 171 and 172).

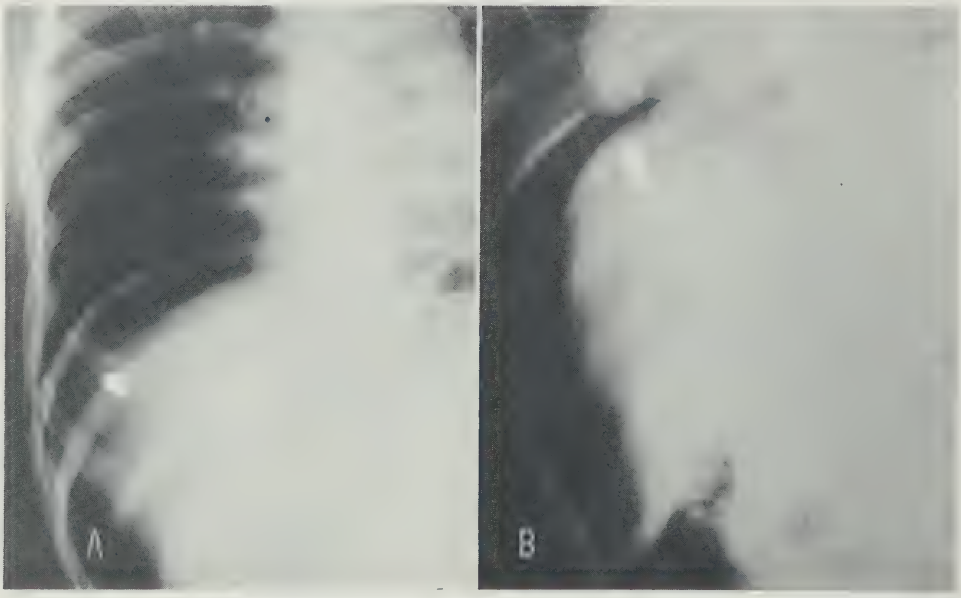

FIGURE 169.—Localization of foreign bodies in relation to hemidiaphragm and liver by pneumoperitoneum. A. Posteroanterior depiction. B. Oblique (right posterior) depiction.

RADIOGRAPHY IN THORACOABDOMINAL WOUNDS

Pleurography proved a useful method in the evaluation of any suspected thoracoabdominal wound. The technique included instillation into the pleural cavity of 30 cc. of Lipiodol, postural dispersion of the medium, and radiography to detect any transdiaphragmatic extension.

The evidence of a tear was unequivocal, and only very occasionally, as, for instance, when a perforation was sealed over transiently, was the result of this type of examination misleading. The technique represented, in fact, a distinct improvement in the evaluation of diaphragmatic lesions. In the past, the classic radiologic findings had been obtained only infrequently; the films were complicated by the presence of associated intrathoracic pathologic processes.

The pattern of the transdiaphragmatic extension of the opaque agent was frequently useful in determining the source of subdiaphragmatic or hepatic suppurative processes that often complicated these wounds. Indirect findings associated with thoracoabdominal wounds included, in the order of frequency, elevation and fixation of the hemidiaphragm; paradoxical motion; pleural effusion; and subphrenic gas-fluid shadows. None of them was a constant X-ray finding.

WOUNDS OF THE CHEST

Blast injuries.—Radiographic findings in blast injuries of the lung (figs. 173 and 174), while fairly definite, were not pathognomonic. These injuries were observed in patients received in hospitals after explosions of buzz (V–1) bombs in England, Belgium, and Holland, and in casualties from artillery blast. No instances of immersion blast were observed.

Radiographic signs, which were in accord with reported microscopic findings and necropsy observations, included atelectasis from bronchial occlusion, hemorrhage and effusion into alveoli and interstitial tissues, failure of the lungs to collapse when the chest was opened because of air trapped in the alveoli, free blood in air passages, bleb formation, and pleural effusion. Other typical findings included localized areas of density, which might clear or increase. The tendency to peripheral rather than central involvement pointed to trauma of the chest wall.

Up to the end of the war, it was often impossible to make a prognosis from a single radiograph because of complicating injuries and the fleeting character of pulmonary findings in less severely injured patients. Serial studies which showed definite clearing of areas of density, whether slowly or rapidly, gave ground for optimism as far as the lungs alone were concerned.

Empyema.—Acute empyema of traumatic origin was frequently associated with foreign bodies lying in close relation to the pleural space. The empyema space could be mapped by pleurograms, which sometimes demonstrated an occult thoracoabdominal communication as well. After operation, the postoperative empyema cavity was again studied by serial radiographs, including pleurograms and radiographs of any sinuses which might be present. Such sinuses were of many origins, including underlying parenchymal or costal lesions, inadequate drainage, foreign bodies, occult or stenotic tracts, and bronchopleural communications.

Clotted hemothorax.—By the time of the Normandy invasion, the introduction of new surgical procedures in the Mediterranean theater, particularly decortication of the lung, required specialized radiographic studies of the chest beyond those described in connection with foreign bodies (p. 463). The radiographic pattern in hemothorax consisted of the usual signs of a diffuse or loculated pleural effusion. The surgical importance of decortication to restore lung function required a search for X-ray signs which would indicate clotting of the hemothorax. Radiographic case studies, repeatedly checked by thoracentesis and thoracotomy, established the following signs as possible radiographic evidence of clot formation:

1. Development of multiple areas of rarefaction, usually with fluid levels.
2. Progressive expansion of the fluid levels, with changes in the contour of the fluid line.
3. Appearance of mottling in an effusion of previous uniform density.
4. Evidence of traction involving the mediastinum, fissures, and diaphragm.

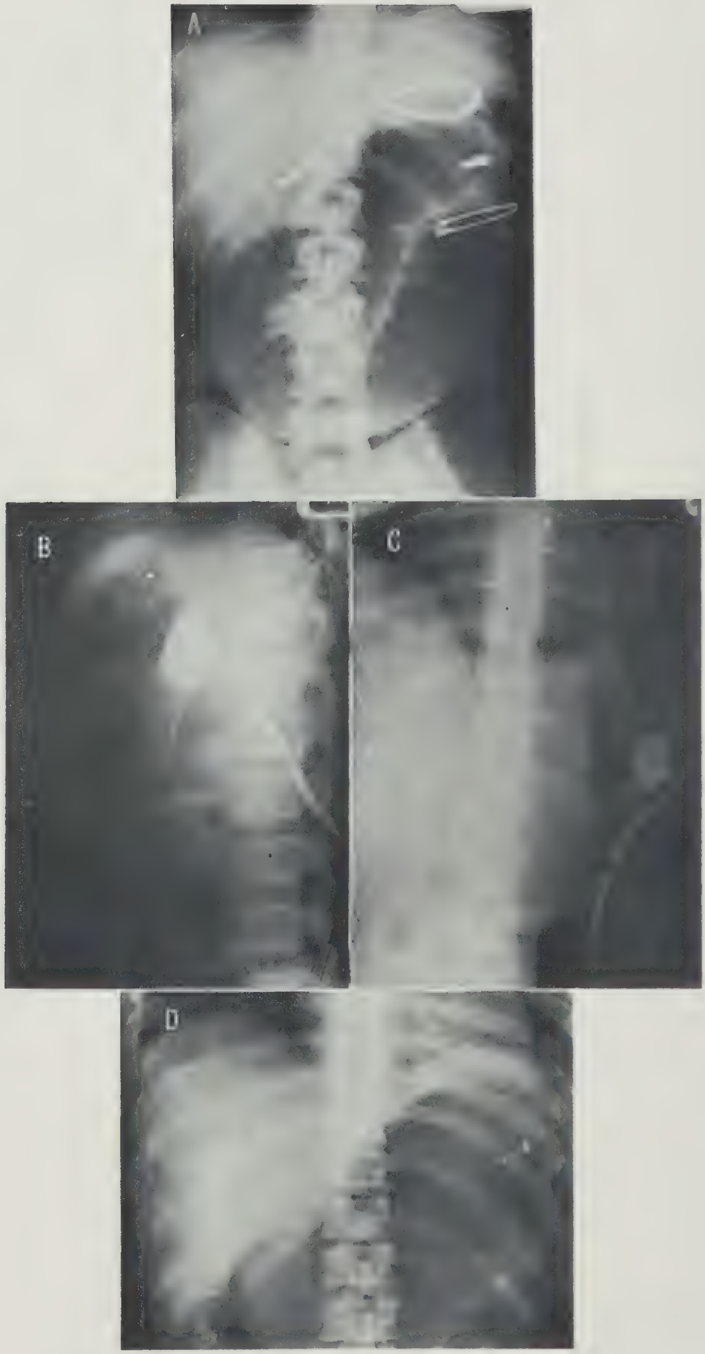

FIGURE 170.—*See opposite page for legend.*

5. Direct evidence of a cortex in association with a pneumothorax, with the parietal thickening usually appearing first and exceeding the visceral thickening.

After decortication, fluoroscopy proved a rough gage of restored lung function. Special attention was devoted to the diaphragmatic excursion; the intercostal expansion, with respect to width and symmetry; and the degree of aeration.

Missile tracks in the lung.—An interesting radiographic finding occasionally noted in chest trauma was missile tracks in the lung parenchyma. They were demonstrated as dense shadows, which were caused by interstitial infiltration or hemorrhage, or as hollow, translucent tracts surrounded by a dense shadow indicating infiltration into the lung parenchyma (fig. 175). The amount of hemorrhage or infiltration along the course of the missile appeared to be proportional to the velocity of the missile. In uncomplicated cases, the end result of this finding was a small fibrous band through the lung parenchyma.

FOREIGN BODIES IN THE EXTREMITIES

Localization of foreign bodies in the extremities was, as a rule, best accomplished by anteroposterior and lateral radiographs. Fluoroscopic orientation by the table device was not so practical, partly because the wounds and their coverings prevented marking the skin and partly because the surgical approach to the foreign body might not be decided upon until after the radiographic study. Marking the skin, therefore, even if it was feasible, might not be carried out on the proper aspect of the extremity.

Lateral radiographs of the extremities could be made with the patient supine, and this position was always used when movement caused pain.

Arteriography, which was used in selected cases, was often of great diagnostic value (fig. 176).

FIGURE 170.—Radiograph of abdomen after injury to bowel, resulting from penetration of left lumbar region by high explosive missile. A. Posteroanterior projection. Gas pattern does not differ from pattern in perforated injuries in which the missile was not retained in the abdomen. B. Same, lateral decubitus. C. Same, after relief of obstructive symptoms and development of splenic abscess. Abscess cavity has been injected with Lipiodol through sinus tract in left flank. Lipiodol is seen in abscess cavity and in portal circulation in right lobe of liver. D. Anteroposterior radiograph, showing small amount of Lipiodol still in abscess cavity, and considerable still in portal circulation in right hepatic lobe. The Lipiodol probably entered the portal circulation through a branch of the splenic vein in the necrotic abscess wall. The patient improved rapidly and was asymptomatic on evacuation to the Zone of Interior.

FIGURE 171.—Rupture of spleen. Anteroposterior roentgenogram, taken 5 days after injury, shows diffuse enlargement of spleen and impingement of upper pole on gas shadow of fundus. Roentgenograms, taken immediately after injury, revealed none of these findings. Intracapsular hemorrhage was found at splenectomy.

INJURIES OF THE CENTRAL NERVOUS SYSTEM

Cranial injuries.—The head injuries sustained in the fighting in Normandy were most frequently penetrating wounds of the skull. The large numbers observed, especially at neurosurgical centers, permitted radiologists to develop efficient techniques of stereoscopic radiography which, with minimal disturbance to the patient, produced accurate localization of bone fragments, especially in relation to venous sinuses.[1] This was an important consideration because of the importance of sinus thrombosis.

[1] In commenting on a statement in the history of neurosurgery in World War II (*14*), that radiographs taken in forward hospitals in the Mediterranean theater were not always useful, Dr. R. Glen Spurling, one of the editors for neurosurgery and Senior Consultant in Neurosurgery in the European theater, wrote as follows: "The difficulty described with roentgenograms taken under field conditions in the Mediterranean theater was not encountered in the European theater, probably because in the latter theater Col. Kenneth D. A. Allen, MC, Consultant in Radiology, personally supervised every army and communications zone medical installation to be certain that useful films were being produced. Many experienced neurosurgeons stated that some of the finest roentgenograms of the head which they had ever used were made in evacuation hospitals in which the only equipment was a portable X-ray unit and a stationary grid."—A. L. A.

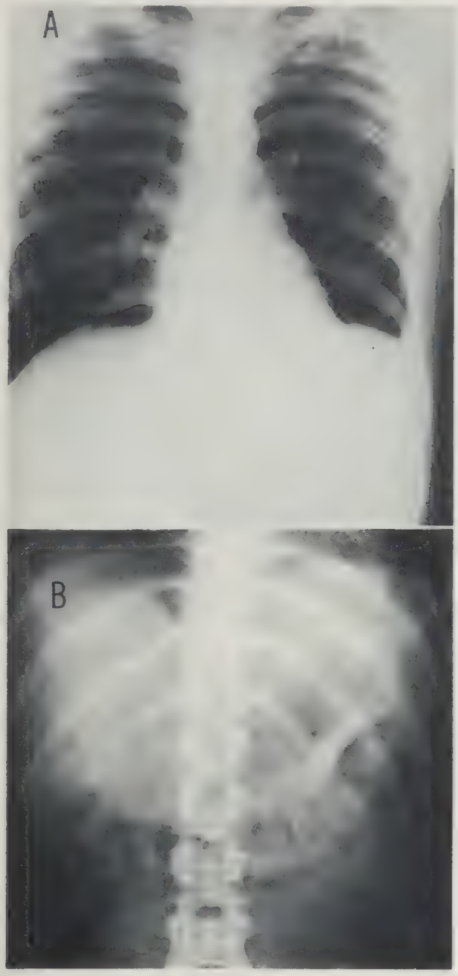

FIGURE 172.—Rupture of spleen. A. Anteroposterior roentgenogram of chest, 3 days after injury, showing slight elevation of left diaphragm and obliteration of left costophrenic sulcus. Fluoroscopy showed lagging of left diaphragm. B. Anteroposterior projectión of abdomen, showing increased space between diaphragm and superior border of gastric fundus. Final diagnosis was capsular laceration of spleen with hematoma.

The low incidence of osteomyelitis secondary to penetrating wounds of the skull was notable and was probably to be explained by early debridement and by the use of chemotherapeutic and antibiotic agents, including penicillin. The most common form of bone infection encountered was a circumscribed osteomyelitis adjacent to the area of injury and contamination.

The frequent occurrence of diastatic fractures was interesting. Traumatic suture diastasis is described by some authorities as limited to children, but the radiologic experience in the European theater showed that it is by no means uncommon in both young and middle-aged adults. Suture separation followed any type of trauma, including gunshot wounds. It was sometimes, but not always, accompanied by fractures of the involved bones.

The demonstration and localization of intracranial bone fragments and

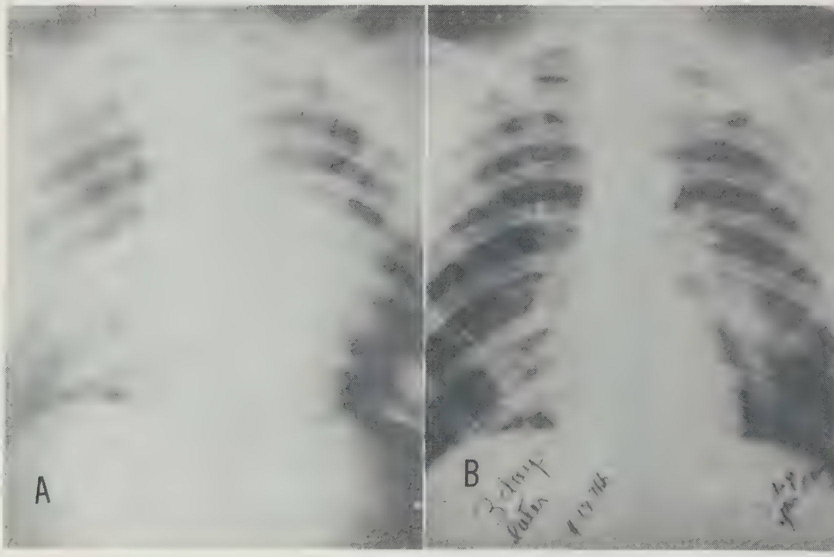

FIGURE 173.—Blast injury of chest from flying bomb. A. Anteroposterior radiograph, 3 hours after injury. B. Same, 3 days later. Note marked resolution.

metallic foreign bodies were extremely important to the neurosurgeon and placed a heavy responsibility upon the radiologist. Because of their clinical significance, care had to be exercised in distinguishing between bone chips impacted against the falx and physiologic calcification within this structure.

Radiographic findings were frequently lacking in head injuries, as increased intracranial pressure was usually of short duration, and bony changes, when they were present, were minimal. In most cases, the pineal gland was not calcified.

Skull fractures extending into fluid-containing cavities were sometimes associated with aeroceles. In such cases, gas was frequently found within the subarachnoid space, within the brain substance, or within the ventricular system. Radiologic diagnosis was of prime importance in this complication, and upright films were desirable to demonstrate the gas-fluid level.

Occasionally, when the position of the head was changed, metallic foreign bodies in cystic or degenerated areas of cerebral tissue or within an abscess cavity were observed to move. They were also observed to move in the presence of expanding masses. The most frequent intracranial masses encountered were cerebral abscesses, which complicated about 5 percent of penetrating head wounds, and subdural and intracerebral hematomas, which occurred in about 2 percent. Radiographic studies usually proved to be the essential means of diagnosing and localizing these lesions. In specialized centers, air contrast studies were done in most casualties with suggestive clinical evidence of mass lesions.

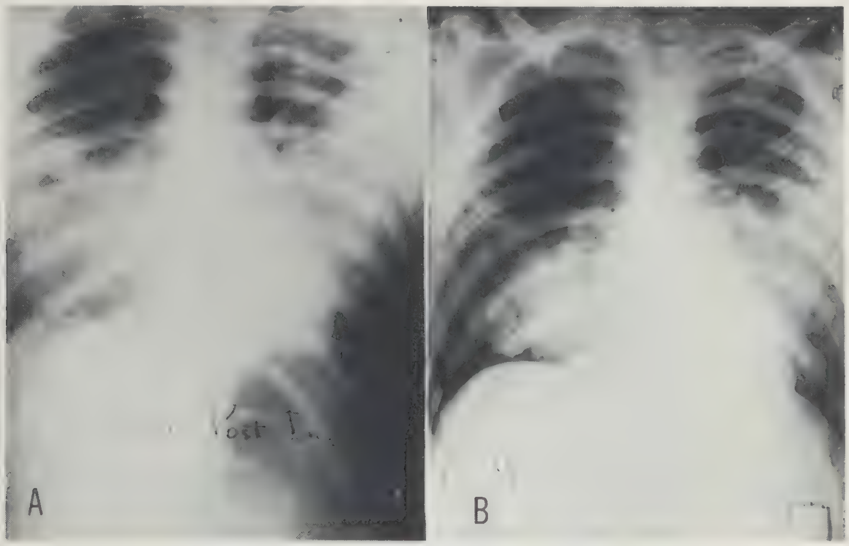

FIGURE 174.—Blast injury of chest and brain from flying bomb. A. Anteroposterior roentgenogram, 6 hours after injury. B. Same, 42 hours later. Note multiple areas of hemorrhage throughout the parenchyma of both lungs. The patient died 2 days later, after craniotomy. Post mortem examination showed multiple areas of hemorrhage in both frontal lobes. Histologic examination showed rupture of alveoli and hemorrhagic extravasation.

Spinal Cord Injuries

Wounds involving the spine were common in World War II, probably because of the artillery "time fire," and most of them produced neurologic symptoms. Missiles that passed through the spinal cord or cauda equina sometimes caused severe destruction of nerve tissue. Plain roentgenograms in such cases almost invariably showed marked fragmentation and deformity of the vertebrae. Traumatic spondylolisthesis was occasionally seen. Civilian-type fractures were fairly frequent (fig. 177).

Missiles frequently passed through only a portion of a vertebra, producing neurologic manifestations, but only slight bony distortion on the radiographs. Careful search by means of stereoscopic oblique films revealed so-called shatter or perforating fractures of laminae, pedicles, or articular processes, with little or no gross deformity.

Myelography.—In the type of case just described, in which plain radiographs were not useful, myelography with Pantopaque (ethyl iodophenylundecylate) was found to be of great value in localizing the area of dural compression and permitting its evaluation. By this technique, the vertebral contours and the irregularities of the neural canal were well visualized.

Myelography was also useful in the localization of opaque foreign bodies

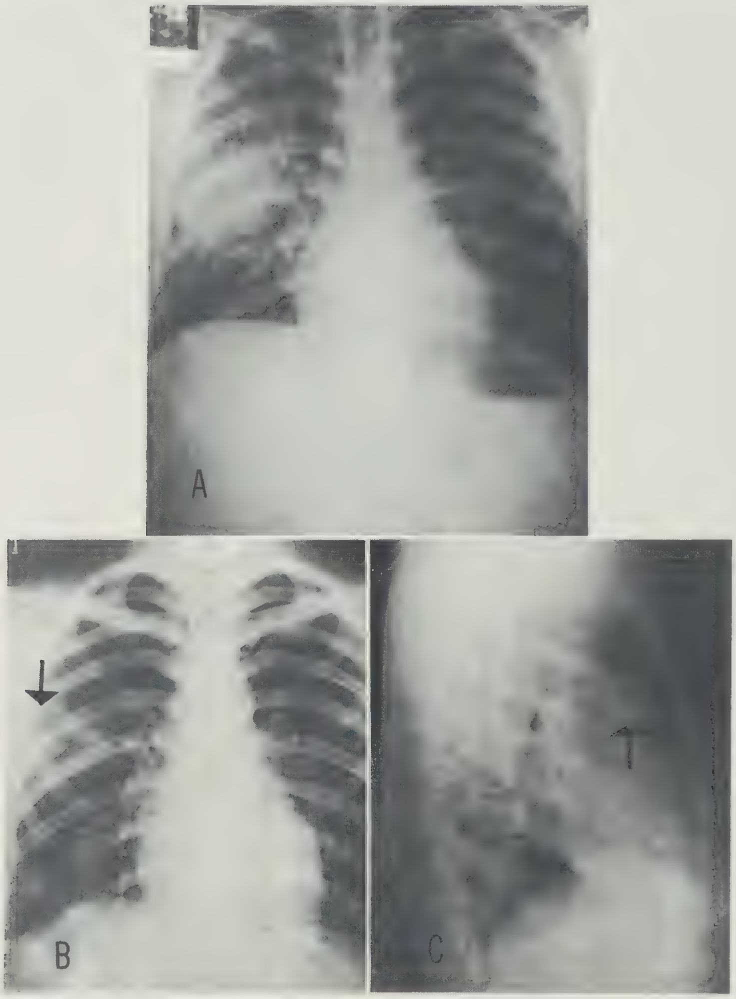

FIGURE 175.—Radiographic study of severe perforating wound of right chest, with compound comminuted fracture of fourth rib in anterior axillary line. A. Posteroanterior radiograph, 5 days after wounding, showing parenchymal infiltration caused by laceration of lung tissue. B. Posteroanterior radiograph, 13 days after injury, showing hollow missile track in right lung surrounded by small area of reaction. C. Lateral radiograph made at same time and showing missile track and reaction more clearly.

in cases in which plain radiographs, usually adequate, were not diagnostic. Myelography provided more accurate localization of the objects in relation to both the neural canal and the subarachnoid space. Small bone fragments and nonopaque foreign bodies that could not be identified on plain films were also found by myelography (fig. 178). The use of Pantopaque, with its almost

FIGURE 176.—Femoral arteriography. Arteriogram, made at operation, disclosed arteriovenous fistula (lowermost arrow) with femoral artery superimposed on shadow of femoral vein (upper arrow). The clinical diagnosis in this case was false aneurysm, medial aspect of femoral artery, in left mid thigh. The findings illustrate the value of arteriography in occult vascular lesions.

complete absence of side effects and its easy removal, gave great impetus to myelography, which proved accurate as well as useful. When surgery was performed, there was usually very close correlation between the myelographic and the surgical findings.

Lt. Col. Charles L. Hinkel, MC, and Capt. Russell L. Nichols, MC, collected and reported a number of interesting cases studied by myelography at the 98th General Hospital (*15*).

RADIOLOGIC DIAGNOSIS OF GAS GANGRENE (CLOSTRIDIAL MYOSITIS)

Although cases of air cellulitis and even air myositis with regular distribution caused by anaerobic organisms other than *Bacillus welchii* were relatively numerous, actual instances of clostridial myositis were very few in the European theater. Radiographic examination alone was not reliable for

FIGURE 177.—Study of fractures of lumbar transverse processes, part of day's work in X-Ray Department, 7th General Dispensary, London, 1942.

diagnosis, and radiologists were warned against depending on this method in Circular Letter No. 101, Office of the Chief Surgeon, European theater, issued on 30 July 1944, as follows (*16*):

Radiographic depiction of gas in the tissues, regardless of its distribution, does not necessarily indicate gas gangrene, and, unless other clinical signs and symptoms are present, should be disregarded.

Colonel Hinkel and Captain Nichols, at the 98th General Hospital, who were particularly interested in gas gangrene, wrote of it, as follows (*17*):

In essence, we had noted that numerous cases of pneumothorax and large hematomas seen following the war wounds frequently broke down in a characteristic sequence.

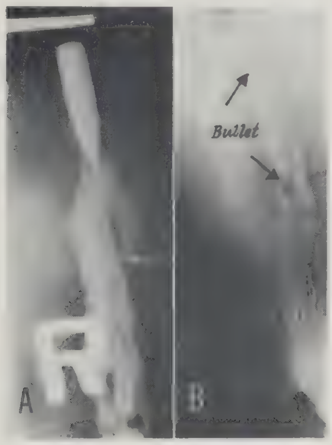

FIGURE 178.—Myelograms, showing complete spinal block at level of foreign body. The shell fragment was removed from the spinal canal, 45 days after wounding, and complete recovery was attained, 8 weeks after surgery. A. Posteroanterior projection. B. Lateral projection.

These collections of blood would first show a few scattered tiny gas bubbles and subsequently would break down to look like a sponge and finally would hemolyze to a complete large fluid cavity. We isolated numerous organisms from various patients that showed such a characteristic sequence and grew the organisms in clotted blood and showed the successive X-ray pattern; first with small bubbles and later with the spongelike pattern. The strange part was that this occurred with *Clostridium welchii* growing in such confined collections of blood without the characteristic anticipated clinical reaction.

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CHAPTER XVIII

Radiation Therapy

Kenneth D. A. Allen, M.D.

EVOLUTION OF POLICIES

As early as February 1943, it had become evident that if superficial X-ray therapy could be provided overseas, many officers and enlisted men who were being evacuated to the Zone of Interior could be retained for service in ETOUSA (European Theater of Operations, U.S. Army). Civilian experience had proved that painfully disabling plantar warts, for instance, could be treated without hospitalization and could be rendered painless, either permanently or for many months, by a single X-ray treatment. Similarly, certain inflammatory skin diseases, such as fungous infections, some disabling types of eczema, and other dermatitides also responded to from one to three X-ray treatments. It was thought—and events proved the correctness of the presumption—that the salvage of manpower in these and other categories would justify the use of X-ray therapy overseas.

Treatment in British hospitals.—Before X-ray facilities were set up in U.S. Army hospitals, British civilian therapists were extremely cooperative in arranging to treat patients who required this form of therapy. The number of treatments was necessarily limited because the British therapists were already seriously overworked with their own cases; they were, however, most cooperative and generous in rendering this aid. Contacts which proved extremely helpful were made in March, April, and May 1943, with the Professor of Therapeutic Radiology, Prof. W. B. Windeyer, and the Director of Therapeutic Radiology of the Christie Hospital, Manchester, Dr. Ralston Paterson (p. 330).

Each civilian center selected for treatment of U.S. Army patients was visited before it was selected and was visited periodically thereafter.

Practical considerations.—Before X-ray therapy was permitted in U.S. Army hospitals, decisions had to be made concerning three important matters: (1) Who should administer it; (2) on what type of cases it should be used; and (3) what equipment should be considered essential.

The decision to carry out X-ray therapy in the European theater was announced in Circular Letter No. 46, Office of the Chief Surgeon, European Theater of Operations (*1*). It was arrived at by consultation between the

Senior Consultant in Radiology and the Senior Consultant in Dermatology. It involved the following considerations:

Personnel.—It was agreed that X-ray therapy would be given only by qualified therapeutic radiologists, in their respective X-ray departments, in consultation with dermatologists. This decision was arrived at after due consideration of such matters as the quarters in which therapy would be given, the care of machines, technical assistants, record-keeping, and X-ray protection. The Chief Surgeon, ETOUSA, acting upon the advice of the Senior Consultant in Radiology, specifically authorized individual radiologists to administer therapy. All of those appointed had MOS (Military Occupational Specialty) ratings of 3182; that is, they were authorized to practice therapeutic radiology as well as diagnostic radiology, but they were not authorized to handle radium.

It should be emphasized that the authorization to administer X-ray therapy was given to the radiologist, never to the hospital. On the other hand, the selection of radiologists also took into consideration the location of his hospital and the proximity of other hospitals.

Equipment.—Administration of X-ray therapy was not permitted in any hospital in the European theater unless an r-meter was available. Delay in procuring this essential item greatly delayed the implementation of the authorization for therapy. On 13 July, and again on 10 August, 1943, r-meters were requisitioned from the United States. By February 1944, when they had not yet been received, the number of soldiers who required X-ray therapy, even under a strict regimen of selection, was overloading the already overworked British civilian therapists, whose cooperation, however, continued ungrudgingly. After another strenuous effort had been made to procure r-meters, it was learned on 7 March 1944 that these instruments were afloat. They were finally received in April 1944. Lack of this equipment caused another delay when X-ray therapy was instituted on the Continent.

Criteria for selection of cases.—Generally speaking, patients were selected for treatment on the basis of the criteria set up by Capt. Gustave Kaplan, MC, and 1st Lt. Joseph B. Stull, MC, and approved by Lt. Col. (later Col.) Kenneth D. A. Allen, MC, in consultation with Col. Donald M. Pillsbury, MC, Senior Consultant in Dermatology, ETOUSA, as follows:

1. The condition present furnished a definite indication for use of this modality.
2. The condition interfered with the patient's military duties.
3. Referral must be by a competent dermatologist.
4. Other types of therapy had proved unsuccessful.

Underlying these criteria was the practical consideration that no patient should be treated unless there seemed a reasonable chance of his returning to full duty after not more than three treatments.

Techniques.—In the circular letter in which X-ray therapy was authorized in the European theater, instructions were given for its administration,

and a simple form was provided for recording treatment. The instructions covered the procurement of a minimum of apparatus and protective devices before treatment could be instituted. They also covered the maximum dosage to be used in single and serial treatments and the size of the portal.

Contrary to expectations, although these instructions were arbitrary, the radiotherapists in the theater accepted them cheerfully and observed them carefully. In no wise did the directions reflect upon the ability of the therapist. They were considered necessary because of the exigencies of treatment in a theater of operations, the paucity and crudeness of the equipment available, and the possibility of future compensation claims.

The Senior Consultant in Radiology and the regional consultants observed closely the work done in all therapy centers.

ESTABLISHMENT OF TREATMENT CENTERS

During the course of the war, radiologists at the 2d, 5th, 43d, 50th, 53d, 58th, 67th, 79th, 108th, 117th, 131st, 137th, 187th, 192d, and 298th General Hospitals were authorized to administer superficial X-ray therapy. A therapeutic radiologist was sent to the 16th Station Hospital in London and authorized to administer superficial therapy for the London area in order to relieve the pressure upon the British civilian radiologist at Middlesex Hospital, Dr. W. B. Windeyer.

Although these 16 hospitals were designated as therapy centers, not more than 8 ever functioned at any one time because the military situation required movement of hospitals and personnel.

By 20 August 1944, it had become obvious that a therapy center was necessary on the Continent. The Chief of the Finance and Supply Division, Office of the Chief Surgeon, ETOUSA, was therefore requested to procure five additional r-meters. The request was duly sent to the Office of The Surgeon General, but because none of them was received before the liberation of Paris, many officers and enlisted men who could otherwise have been retained on the Continent had to be evacuated to the United Kingdom for treatment.

The problem was solved when the Beaujon Hospital in Paris was captured and was taken over by the 108th General Hospital. It had been occupied by the Germans and its deep X-ray therapy apparatus was recovered intact because, it was said, the German personnel who evacuated the hospital believed that they would return shortly. The radiologist of the 198th General Hospital was authorized to treat skin epitheliomas and to administer both deep and superficial therapy. All X-ray measuring devices, however, had been removed, and it was not until October 1944 that an r-meter became available, brought by hand by Colonel Allen after one of the X-ray therapy centers in the United Kingdom had closed.

Because of the continued lack of r-meters, the 108th General Hospital in Paris was the only treatment center on the Continent until late in the spring

of 1945, when the radioloigst at the 43d General Hospital was authorized to administer therapy. Even then, at least five other centers could profitably have been designated as treatment centers.

There was considerable pressure from the Third U.S. Army to establish a treatment center at Army level, so that such conditions as plantar warts could be treated without evacuating personnel to the 108th General Hospital. Colonel Allen responded to the demand by borrowing an r-meter from a hospital in England and authorizing Maj. (later Lt. Col.) Frank Huber, MC, at the 12th Evacuation Hospital (p. 400) to investigate the feasibility of administering X-ray therapy in a forward area. Major Huber reported it impractical for at least four reasons: (1) Lack of satisfactory protection; (2) lack of space in forward hospitals for such a department; (3) the variability, unreliability, and inadequacy of available electrical power; and (4) the total commitment of available apparatus for diagnostic needs. The request of the Third U.S. Army therefore had to be denied.

CASELOAD AND RESULTS

Total statistics for X-ray therapy in the European theater are not available; for one thing, it was not practical to try to obtain them from the busy British civilian therapists who treated large numbers of patients before the U.S. Army hospitals took over the task. Figures which are available (representing about two-thirds of the total number of patients treated in the United Kingdom between 10 May 1944 and 31 May 1945) are as follows:

Disease	*Number of patients*
Plantar warts	442
Miscellaneous skin conditions	699
Fungous infections	79
Painful acne	73
Furunculosis	50
Epitheliomas	48
Keloids	33
Sycosis barbae	30
Dyshidrosis	27
Other conditions	162
Total	1,643

Other conditions treated included arthritis, cervical adenitis, subdeltoid bursitis, cellulitis, eczema, acute folliculitis, herpes zoster, hyperkeratosis, impetigo, lichen planus, lichen simplex, molluscum contagiosum, mycosis fungoides, otitis media, otitis externa, psoriasis, parotid fistula, pruritus ani, chronic perlèche, painful Sudeck's atrophy, inflamed sebaceous cyst, tenosynovitis, tinea cruris, verruca, lymphoblastoma, and pompholyx.

TABLE 13.—*Therapeutic caseload, 108th General Hospital, Paris, October 1944–May 1945*

Month	Patients	Treatment
1944		
October	7	10
November	13	19
December	18	52
1945		
January	31	84
February	64	144
March	143	264
April	173	336
May	232	479
Total	681	1,388

A portion of the 8 June 1945 report by the radiotherapist at the 108th General Hospital, Maj. (later Lt. Col.) Alfred C. Ledoux, MC, shows clearly the need for X-ray therapy on the Continent. Among the conditions treated were the following:

Disease	*Number of patients*
Dermatoses (all types)	282
Verruca	175
Skin malignancies and allied conditions	48
Pruritus	21
Arthritis and peritendinitis	14
Keloids	13
Lymphoblastoma and allied conditions	6
Parotitis	2
Unclassified	5

The increasing use of the facilities of the 108th General Hospital for X-ray therapy (table 13) made clear the need for this modality on the Continent. It should be emphasized that of the 681 patients treated, 419 were on an outpatient status throughout their courses of therapy.

Results.—Results of superficial X-ray therapy were generally good, especially as compared with the unsatisfactory results of previous prolonged medical treatment. The value of this method in the treatment of disabling plantar warts has already been mentioned; the therapists at one hospital insisted that correct shoes be prescribed for these patients if the best results were to be obtained. Fungous infections responded well. At the 108th General Hospital, dermatoses accounted for almost half of the patients treated, and those with moderate to severe epidermophytotic infections, which had kept them noneffective for long periods of time under other therapy, could be promptly returned to duty. Consistent followup was naturally not possible, because of troop movements, but either cures or good remissions were obtained in most of the men followed.

Results at the 108th General Hospital were somewhat less good in other conditions. Patients with peritendinitis with calcification experienced some amelioration of their symptoms, but not more than half were cured. The same percentage of good results was obtained in pruritus ani, and, again, most of the other patients had some amelioration of symptoms. The radiologist at this hospital, Major Ledoux, did not recommend treatment of keloids, on the ground that they were not sufficiently disabling. One patient with postoperative parotitis was cured by a single X-ray treatment, and another, with chronic parotitis, was improved.

At the 187th General Hospital, Everleigh, Tidworth, England, the radiologists, Maj. Granville W. Hudson, MC, and Maj. (later Lt. Col.) Harry A. Miller, MC, reported a high percentage of good results in skin conditions, cellulitis, and localized infections. Patients with plantar warts were told to return in 3 weeks if they were still in the vicinity and had not obtained relief; if they regarded themselves as cured, they need not return.

This was not a satisfactory technique of followup, but was practical in that the objective of treatment was to keep the patients ambulatory. Most of the patients with plantar warts either returned reporting themselves cured or did not return at all. Only two recurrences were personally observed.

The dosage at this hospital for plantar warts 1 cm. in diameter or less was 1,200 r. This dosage did not produce a disabling reaction and was considered adequate for cure. The radiologists at this hospital, like several others, called attention to the fact that superficial X-ray therapy would be more useful if battalion surgeons were made aware of its availability.

The radiologists at the 117th General Hospital, Frenchay Park, Bristol, England, Maj. (later Lt. Col.) Bernard C. Desrochers, MC, and Capt. Wendell C. Matthews, MC, reported that X-ray therapy achieved either cures or good results in all the patients treated. They reported four patients with traumatic salivary fistulas, all of whom had marked improvement after the first treatment, with a dosage of 75 r. Three of the four were cured after two treatments, and the fourth after a third treatment.

DEEP X-RAY THERAPY

Circular Letter No. 46, Office of the Chief Surgeon, ETOUSA, declared that deep X-ray therapy, as well as superficial therapy, was essential in the theater, to render transportable patients suffering from such neoplastic conditions as Hodgkin's disease, lymphosarcoma, thymomas, and certain carcinomas, especially those involving the mediastinum and causing sudden interference with respiration. All such patients received air transport priority to the Zone of Interior, but even with it, they were not always transportable without preliminary treatment. The experience of the 108th General Hospital, one of the centers in which deep therapy was permissible, is typical: Of the six patients with lymphoblastoma, one succumbed to his disease during the

course of treatment. The remaining five men, after treatment, were sufficiently improved to be classified as presently transportable to the Zone of Interior.

Since a single massive dose of X-ray was known to cure most skin neoplasms without hospitalization, Circular Letter No. 46, Office of the Chief Surgeon, ETOUSA, specified that these lesions might be treated in the European theater and also named the British civilian therapists who might administer the therapy.

Although treatment of skin neoplasms was accomplished in most cases with 100-kv. peak dosage, this type of therapy was not regarded as superficial. The civilian therapists listed in Circular Letter No. 46 used the same dosage. At the 108th General Hospital, 48 patients, chiefly officers, were treated in this manner, without need for hospitalization or later evacuation to the Zone of Interior in any instance.

One patient with carcinoma of the lip who was treated in the European theater was especially memorable because of the circumstances of his treatment and because he was a colorful four-star general who was a key figure in the victory over Germany. The story began with a telephone call the Senior Consultant in Radiology received from Maj. Gen. Paul R. Hawley, Chief Surgeon, ETOUSA, to the effect that a military VIP had a lesion of the lower lip and where would the radiologist see him. It was agreed that he should be seen that same day, in the office of Dr. Ralston Paterson, in Manchester. The patient did not appear, and no explanatory telephone or other message was received.

A week later another telephone call, similar to the first, was received, and a second appointment was made, at the Department of Radiology, Middlesex Hospital, London. This time, the appointment was kept. The patient stormed in and impatiently inquired how long it would take to treat him. After he had been examined by Dr. W. B. Windeyer, radiotherapist at the hospital, and Colonel Allen, he was told that he would need three spaced treatments. That would not do, said the general, it was now or never, and he made it quite plain that he did not have a high opinion of "medical quacks."

Under the circumstances, there seemed nothing to do but heed the ultimatum that only one treatment would be permitted, and the necessary irradiation was delivered in a single massive dose. Although neither radiologist ever saw the patient again, both received reports that he had had a good scar formation, followed by a perfect therapeutic result.

RADIUM

Although the Senior Consultant in Radiology had ample opportunities to procure radium for therapeutic use, he did not regard this modality as necessary in the wartime circumstances in the European theater. During the war, there was not a single instance in which it was believed to be indicated. All patients who needed short-wave radiation were evacuated to the Zone of

Interior. If they were nontransportable, they received preliminary deep-ray irradiation, as just described. In two cases of Hodgkin's disease, the condition was so far advanced when the patients were first seen that radium would have been of no avail.

REFERENCE

1. Circular Letter No. 46, Office of the Chief Surgeon, Headquarters, European Theater of Operations, U.S. Army, 23 Mar. 1943.

Part V

ASIATIC-PACIFIC THEATER

Pacific Ocean Areas

CHAPTER XIX

General Considerations

Charles W. Reavis, M.D.

For the United States, World War II began and ended in the Pacific, the period of combat beginning with the attack on Pearl Harbor on 7 December 1941 and ending on 2 September 1945, with the formal surrender of the Japanese in Tokyo Bay. Meantime, the war was fought over almost incomprehensible distances of ocean, with only occasional areas of land between military objectives that had to be achieved. The main objective, Japan, was some 5,000 miles from the west coast of the United States, and U.S. bases in Australia were more than 7,000 miles away from the American mainland.

Industrial facilities were entirely lacking in practically all these areas of ocean. The white man, in most parts of the region, was a stranger to the climate and to the way of life (fig. 179). Indeed, climatic conditions frequently formed part of the opposition to be overcome. Unknown tropical diseases, or known tropical diseases with new and bizarre manifestations, were prevalent in the native populations, and, like another enemy, also had to be conquered. Early in the war, the way back to the Philippines, which had been attacked by the Japanese immediately after the attack on Pearl Harbor (map 2), was a succession of short steps, each strongly contested by the enemy. At the original rate of progress, Tokyo was very far away. By 1944, however, the enormous expansion of carrier aviation had changed the picture. Hops of a thousand miles became practical, and the original step-by-step progress was replaced by the policy of bypassing islands.

MILITARY STRUCTURE

Early in the war, with the Japanese in control of so much of the Pacific (map 2), the best that the Allied forces could do was to establish bases around the perimeter (map 2). On 30 March 1942, the vast Pacific area was divided into two major commands: (1) The Southwest Pacific Area, which included Australia, New Guinea, the Bismarck Archipelago, the Philippines, and most of the Netherlands Indies; and (2) the Pacific Ocean Areas, which included everything else in the Pacific between the Americas and the Asiatic mainland. The Southwest Pacific was under the command of Gen. Douglas MacArthur. The Pacific Ocean Areas, which were divided into North, Central, and South Pacific Areas, were designated a Naval theater and were under the overall command of Adm. Chester W. Nimitz.

FIGURE 179.—Scenes in a Fuzzy-Wuzzy village on New Guinea. A. Native huts, typical of living quarters on New Guinea and adjacent islands. Note the thatched roofs. Sanitary facilities were completely lacking. B. Typical natives. C. Better homes in the village shown in view A. D. Storehouse for yams, the main native food supply.

In April 1945, USAFPAC (U.S. Army Forces, Pacific) was established and all Army troops in the Pacific were placed under General MacArthur's command. U.S. Army Forces, Pacific Ocean Area, then became a subcommand of USAFPAC, as did the Services of Supply organization for U.S.

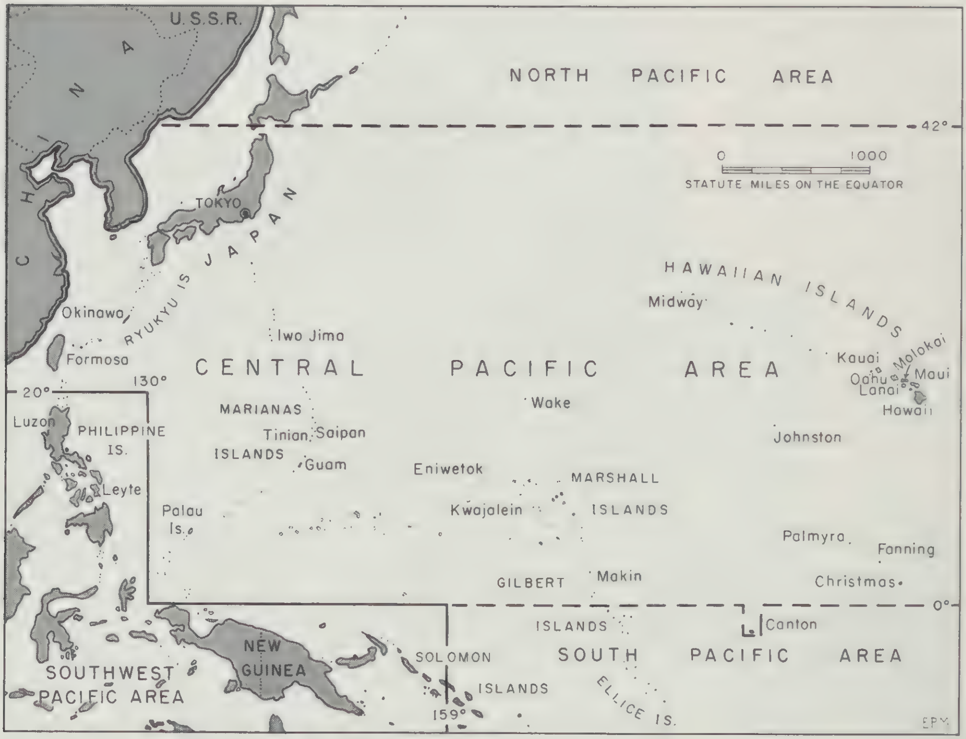
MAP 2.—Pacific Ocean areas, showing area under Japanese control, 6 August 1942.

Army Forces in the Southwest Pacific Area; in mid-1945, these two were redesignated USAFMIDPAC (U.S. Army Forces, Middle Pacific) and USAFWESPAC (U.S. Army Forces, Western Pacific).

CENTRAL PACIFIC

Geography

The geographic and command theater known as the Central Pacific Area (map 3) covered a vast region composed chiefly of ocean. It stretched from the western coast of North America on the east to (exclusive of the Philippine



Map 3.—Central Pacific Area.

Islands) the coast of China on the west. It also extended from the Equator on the south to the 42d parallel on the north. This expanse measured approximately 6,000 miles from east to west and 3,000 miles from north to south.

The Hawaiian Islands in the Central Pacific Area were approximately 2,300 statute miles from the continental United States, from which all troops, medical installations, and supplies of all kinds had to be brought. The war in this area involved problems of (1) transportation of men and supplies over enemy-infested waters to friendly bases and then (2) making landings on enemy-held islands and basing men and supplies on them after they had been occupied.

Landmasses to be occupied in the Central Pacific were all relatively very small, and distances between some of them ranged from 1,000 to 2,000 miles. The smaller islands were flat coral atolls. The larger islands, of volcanic origin, were partly surrounded by reefs.

Medicomilitary Structure

Throughout the war, Army hospitals and other medical units in the Hawaiian Islands remained under the close technical control of the Surgeon,

Central Pacific Area (originally the Hawaiian Department). Medical activities were coordinated by consultants and other personnel from his office, and circular letters and other directives were issued from it.

As the war extended westward, lines of command became less direct, and the Surgeon, Central Pacific Area, had to depend more and more upon his own visits and those of his staff, chiefly his division medical surgeons, assault surgeons, garrison surgeons, and similar personnel to maintain communication with his office and to advise and assist in the formulation and execution of medical policy and procedures. In the Okinawa campaign, the Surgeon's contacts were chiefly with the corps surgeon and the Army surgeon.

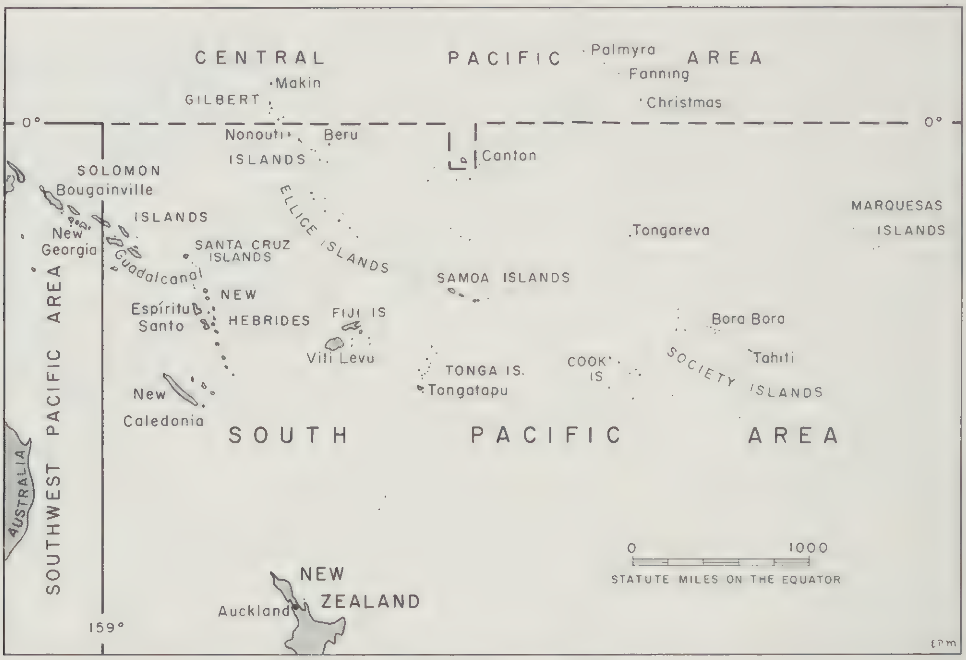
Until almost the end of the war, when Iwo Jima and Okinawa became battlefields, the Central Pacific Area was not a major battle zone for infantry and armored forces when compared to the European theater. It therefore suffered serious shortages of these forces, transportation, and supplies, all of which were necessarily diverted to more active areas. The wise economy of medical officers and enlisted personnel and the wise use of medical equipment and supplies furnished continuing problems for the Office of the Area Surgeon and for all medical commanders in the Area. As the war spread over ever-enlarging areas, available medical personnel had to be spread thinner and thinner, and new medical personnel, including technical specialists, had to be trained on both local and headquarters levels.

Medically, it was often both necessary and expedient to exchange patients, personnel, supplies, and sometimes medical units between the Army and the Navy. This was particularly true under battle conditions and on small islands, on which the care of the wounded was initiated on a narrow beachhead and evacuation was to hospital ships and other transports offshore. When the casualties reached the shore of Oahu, Army medical installations again assumed the responsibility for their care. Later in the war, of course, Army medical facilities were located on intervening islands.

SOUTH PACIFIC

Geography

A glance at the map of the South Pacific Area (map 4) tells almost the entire story of the practice of radiology in this part of the wartime world. It can be expressed in a single word—distance. Some concept of the distances involved may be gathered if one conceives of the upper margin of the South Pacific Area as lying along the Equator for a distance of about 4,000 miles, which is more than the width of the United States. From this long superior margin, the Area reached downward toward the South Pole without a definitive southern boundary. For practical purposes, it extended some 3,500 miles below the Equator, to include the North and South Islands of New Zealand. The headquarters for the entire South Pacific Area was situated at Nouméa,



MAP 4.—South Pacific Area.

New Caledonia, about 1,000 miles north of Auckland, New Zealand, and a distance of 3,351 air miles from San Francisco.

This is an incredibly beautiful part of the world, with its coconut palms, mango trees, acacia, gardenias, hibiscus, oleander, allamanda, crotons, and frangipani plants. But, like other parts of the Pacific, this was also a region of intense heat and humidity, where the difficulties of radiologic practices were like those in other parts of the Pacific.

Medicomilitary Structure

The island commands which functioned under the headquarters at Nouméa varied in number from time to time. At the peak, there were 11: New Caledonia, New Zealand, Fiji, Guadalcanal, Espíritu Santo, Russell Islands, Green Islands, Emirau, Bougainville, and New Georgia. By 1944, these semiautonomous commands had been reduced to four, and the medical problems they presented were further simplified by the fact that the fighting war had moved out of the area and the hospital population consisted chiefly of patients with the injuries and illnesses commonly encountered among garrison troops.

Active combat in the South Pacific Area lasted from 7 August 1942 to 27 March 1944. The Guadalcanal campaign began on 7 August 1942 and was concluded on 21 February 1943. The battle for New Georgia began on 30 June and reached a climax on 5 August 1943 with the capture of its objective,

Munda Airdrome. The main drive moved on to other islands, though some Japanese remained on the island, and combat action did not end officially until 1 October. The battle for Bougainville began on 1 November 1943, and the Japanese withdrawal began on 27 March 1944, though fighting continued for some time afterward. The battle for the Green Islands lasted from 15 February to 20 February 1944.

SOUTHWEST PACIFIC

Military Considerations

Immediately after Pearl Harbor and the fall of the Philippines, the major base for waging war against Japan was necessarily Australia (maps 2 and 5) because it was the only area with any of the facilities required. These facilities were, however, totally inadequate. Australian manpower was limited even before the war, and the meager industrial output of the country was already overcommitted. Practically every item necessary for modern warfare therefore had to be transported from the United States, more than 7,000 miles away. Even in the United States, there was not too much of either manpower or material for the Pacific, for the decision had been made to prosecute the war in Europe more actively, even if it meant delay of activities in the Pacific.

On 18 April 1942, General MacArthur, who had been evacuated from the Philippines, assumed command of General Headquarters, Southwest Pacific Area.

The first actions in the Southwest Pacific were to secure bases in New Guinea (map 6). By the end of 1943, the center of activity in this area was moving steadily northward, and Brisbane, the last and most important base in Australia, was shut down in December 1944. During this same year, the bases on New Guinea (Hollandia, Finschhafen, and Biak) had become staging areas for the invasion of the Philippines (map 7); by March 1944, Finschhafen contained 90,000 troops. By mid-1945, when Leyte had been secured and Luzon was almost secured, the New Guinea bases had ceased to be of major importance.

The military buildup of the bases on the Philippines, in anticipation of the invasion of Japan, proved unnecessary when Japan surrendered on 14 August 1945. U.S. Forces then moved into Japan and assumed the duties of an army of occupation.

Geography

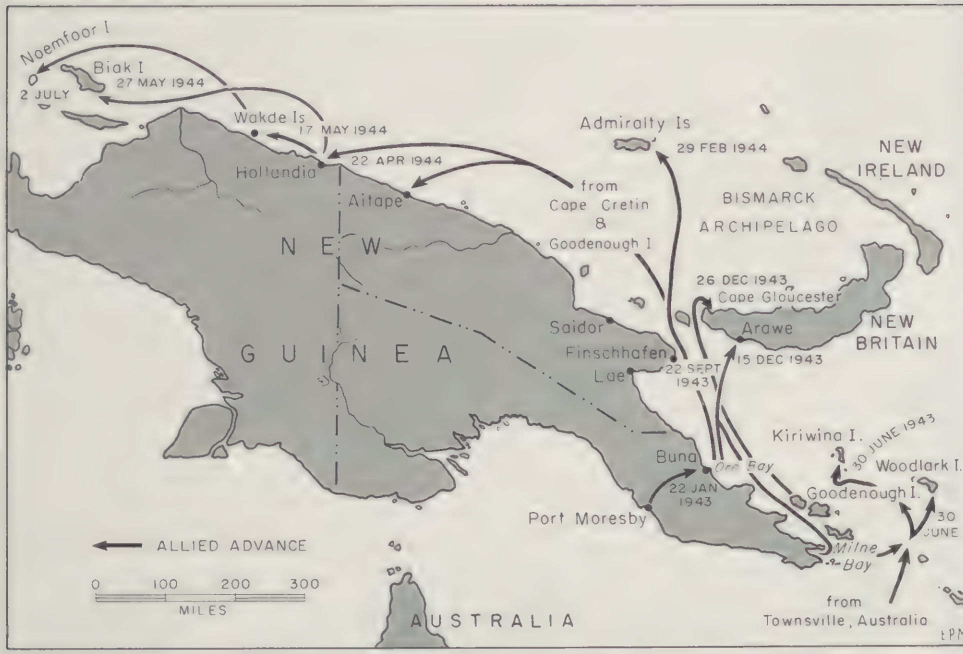
As in other parts of the Pacific, environment was a constant problem in the Southwest Pacific—vast distances between hospital installations and between these installations and headquarters; intense heat; intense humidity;

Map 5.—Southwest Pacific Area.

torrential rains; heavy jungle growth; and tropical diseases of epidemic proportions.

Throughout the campaigns in the Southwest Pacific the story was the same: Hospitals staged, moved, set up, then staged again, moved again, and repeated the endless cycle. It was easy to understand the motto adopted by personnel who worked in the area, "Hurry up and wait."

Staging areas furnished little or no diversion, and very little rest, as might



Map 6.—Allied advance from Townsville, Australia, 1942, to Noemfoor Island, off New Guinea, 2 July 1944.

have been expected in the wilds of New Guinea and the jungles of the Philippines. In fact, if there were hospitals in operation near staging areas, there was always a scramble for temporary duty in them, for the boredom of inactivity affected medical personnel no less than other personnel.

Hospital units on outlying islands were completely isolated and had to handle their medical and other problems as best they could. Supply was always erratic, and the uncertainties of transportation were often compounded by the inefficient handling and storage of equipment, with resulting losses from rain, wind, heat, and tropical humidity.

THE OVERALL PICTURE IN THE PACIFIC

This, then, was the Pacific—an area of complexity of organization and command; a geographic nightmare from the military standpoint; an ultimate target many thousands of miles away from sources of manpower and supply; a secondary war objective, with initial low priorities in supplies and equipment as well as personnel; an area of tropical jungles and tropical diseases, many of them previously unknown to U.S. Army medical officers; an area of often unendurable boredom; but still an area in which victory was finally achieved against almost overwhelming odds.

MAP 7.—Allied advance from bases in New Guinea to Philippines, 1944–45.

The whole picture of war in the Pacific was graphically summarized by Col. John M. Caldwell, MC, Commanding Officer, 54th General Hospital, in the 1945 report of the activities of this hospital in Hollandia:

Beneath the statistic studded crust of the report lies the drama of civilized men in a primitive country fighting miasmatic jungles in steaming tropical heat to provide sanctuary for fighting men on a front 1000 miles northward.

It includes the story of medical troops working 14 hours per day, seven days per week, to handle 17,862 patients while holding the number of fatalities to 25.

It is the story of medical science battling hitherto unknown maladies, of antiseptic surgery far from the paths of civilization, of soldiers improvising successfully to meet the challenge imposed by conditions in the jungle and by arduous supply lines extended over thousands of miles of ocean.

It is the story of weary corpsmen and nurses in mudsplattered uniforms singing

nostalgic carols to the bedridden on Christmas Eve * * * of ministration and administration * * * of blood counts, diagnoses, medication, surgery, statistical reports * * * of bed pans, diets and details.

The staff and personnel of the 54th General Hospital prefer to regard this unit as typically American; as a strong link in the Services of Supply chain * * * tempered in the flame of democracy and forged on the unrelenting anvil of the tropics.

While the foregoing remarks apply to the medicomilitary history of the Pacific Ocean areas in general, they are all specifically applicable to radiology. The history of this specialty in all these areas was intimately related to the problems of transporting hospitals and other medical units over vast expanses of ocean; landing them on enemy-held islands; and then establishing and operating medical units in conditions of tropical heat and humidity, with long lines of evacuation and supply. In at least two respects the problems of radiology were highly specialized: (1) Radiologists could not function without equipment, and (2) their equipment was heavy, space-occupying, easily damaged, and was also highly susceptible to the ravages of the humid climate in which most operations in the Pacific were conducted.

The opinions expressed in this history of radiology in the Pacific are those of the contributors to it, not only those of the authors themselves but also those of the many other radiologists who provided the material upon which the story is based and all of whom were there when the action happened. To understand and appreciate the part that radiology played in the war in the Pacific, one must, of necessity, view it at the level of the individual radiologist, for it was on that level that service was provided. It is not possible to describe radiology west of San Francisco as a composite picture. The span is too great. Only a blur would result.

Central Pacific Area

CHAPTER XX

The Pearl Harbor Experience

Maurice C. Archer, M.D., and *Richard C. Boyer, M.D.*

THE DAYS BEFORE PEARL HARBOR

Surprising and devastating as was the Japanese attack on Pearl Harbor on 7 December 1941, the Hawaiian Department medical personnel and the staff at Tripler General Hospital, Honolulu, were not unprepared for it.

Fully 6 months before the Pearl Harbor attack, the Hawaiian Department Surgeon, Col. (later Brig. Gen.) Edgar King, MC, had completed comprehensive medical plans for implementation in the event of enemy attack or other major catastrophe. These had been coordinated with all medical unit commanders and medical personnel in the Hawaiian Islands and included the use of certain civilian hospitals in Honolulu and outlying islands with stockpiling of necessary medical supplies in them should they be needed. Cooperation with the American Red Cross in its various aspects included in the planning revealed the broad scope and timeliness of the medical preparation.

In addition, late in November, Col. Alvin C. Miller, MC, the Commanding Officer, Tripler General Hospital, called a staff meeting at which he spoke gravely of the seriousness of the international situation and the great danger of a war with Japan. The hospital staff was placed on a 24-hour alert, and its members were instructed to be either in the hospital or at home, within reach of the phone, at all times. Off-duty hours on the beach were discontinued.

The hospital alert continued until 6 December. It was then taken off, so that, the hospital staff understood, the island would not appear to be on a war footing when the peace envoys from Japan stopped there on their way to Washington (it will be remembered that they were in the office of the Secretary of State in Washington when the attack was made on Pearl Harbor). On the Friday before the attack, Capt. (later Lt. Col.) Maurice C. Archer, MC, heard a radio news reporter on Station KGMB say that he hoped the peace envoys were acting "in good faith and were not stalling." The remark was to prove prophetic 2 days later.

THE ATTACK

On 7 December 1941, a special meeting had been planned by the Honolulu County Medical Society for physicians in Honolulu and its vicinity to

hear a lecture on burns by Dr. John J. Moorhead of New York City. Dr. Moorhead had just begun his lecture, to a disappointingly small audience, when bombs began to fall on Pearl Harbor. As a colonel in the Medical Corps Reserve, Dr. Moorhead was called to active duty before the day was over.

All those who have written of or described the Pearl Harbor episode recollect that 7 December was a beautiful, sunshiny day. There were no news programs on Sunday morning, and Captain Archer recalls that as he left the house to go to the meeting just mentioned, he saw numerous puffs of black smoke following antiaircraft gunfire and assumed that they were part of the naval maneuvers that had been carried out on several Sunday mornings in the past. He was casually talking to another medical officer outside the building in which the meeting was held when a civil defense worker rushed up, told them of the Japanese attack, and said that all Army officers had been ordered to report to their posts at once.

Both officers automatically obeyed the order, without stopping to consider that the message had been transmitted by a civilian. By this time, however, it was clear that what was happening was much more than practice maneuvers. The antiaircraft fire had increased. Army trucks raced down the streets towing antiaircraft guns. Private cars were lined up on both sides of the street. Many of them were later found completely demolished or beyond use because of large gaping holes. Only the cars parked in the protection of trees and shrubbery escaped.

By the time Captain Archer arrived at Tripler General Hospital, where he was the assistant radiologist, ambulances were already unloading the wounded from Hickam Field, Oahu. Eventually, hundreds of casualties were brought in. Among the first were troops being flown into the islands from the mainland on a B–17 that had guns but no ammunition to fire in them. The plane had been shot up by Japanese planes which came in on its tail as it set down on the airstrip. The spirit of these troops was typical of that of all the other casualties—raging anger that they had had no chance to fight back.

The close proximity of Tripler General Hospital to the waterfront and to other military installations—it was directly across the way from Fort Shafter, Oahu, T.H.—made it almost inevitable that it suffer some damage from both enemy and U.S. fire, particularly from antiaircraft guns. Many shell fragments fell about the hospital on Sunday, and shortly after 0400 hours the following morning, an air-raid alarm sounded, and shell fragments, presumably from U.S. guns, crashed through the roof and into an operating room. On another, similar occasion, a patient in one of the wards was killed.

One necessary task, done in amazingly quick order, was to blackout all the windows and doors in the wards, administration building and X-ray department, and in the areas around the ramps. When the blackout covers were in place, the trade winds that kept Hawaii generally cool and comfort-

able were no longer effective, and there was considerable discomfort from the humidity.

Other precautions were also taken: No one was allowed to smoke outside the buildings, and flashlights with small blue beams were issued, to prevent collisions with buildings, posts, and other objects.

Numerous alerts, all of which proved to be false but which caused considerable apprehension, sporadic gunfire, and fear that the enemy might return, placed a heavy mental and physical strain on the wounded as well as on the hospital personnel confined with them. For 72 hours after the attack, medical officers, nurses, and other personnel remained on duty almost continuously; their only rest was secured at occasional intervals on the floors of the wards and corridors.

PROFESSIONAL CARE

In the course of the day (7 December), about 400 wounded were admitted to Tripler General Hospital. The orderliness and efficiency with which they were handled were remarkable. The confusion that might have been expected did not occur because the catastrophe, or something similar to it, as explained, had been anticipated and had been well planned for medically.

An entirely new section of one-story buildings located just to the side of the main hospital had not previously been used, but its beds were ready for just such an emergency. Regular Army medical officers knew what their roles were. Equipment was ample, and, because of wise stockpiling, Col. (later Brig. Gen.) Edgar King, MC, Surgeon, Hawaiian Department, was able to dispatch ample medical and surgical supplies to the hospital at once.

As the wounded were carried into the hospital, they were taken to the wards or to the operating rooms, depending upon the urgency of their state. The bodies of about 200 casualties who were dead on arrival were routed immediately to the morgue.

The wounded who required X-ray examination were cared for by the X-ray technicians, either in the X-ray department or with portable apparatus on the wards and in the operating rooms. The radiologists, Lt. Col. (later Col.) John D. Barnwell, MC, and Captain Archer were immediately given additional duties in the receiving and preoperative sections. They also acted as liaison officers between the X-ray department and the operating rooms. Captain Archer, the night of 7–8 December, served for 8½ hours on one of the operating teams.

Although the X-ray department was kept extremely busy, there was no shortage of films, thanks to the wise stockpiling already mentioned. Multiple exposures were often necessary because some casualties had foreign bodies in many locations; frequently, the objects were too numerous to count. The films were read as rapidly as possible, the necessary information was given to the surgeons, and the radiographs were sent to the operating room to be used when the shell fragments were removed.

Many of the wounded had severe skull fractures, brain injuries, chest wounds, and abdominal wounds. Some wounds were closed at once, but more often only partial debridement was performed. Shell fragments were removed whenever it was possible. Tetanus toxoid booster doses were given routinely. Either sulfanilamide or sulfathiazole powder was placed in all wounds. It is a matter of record that later observations proved that local chemotherapy was not only not as useful as it had been thought to be but was sometimes actually harmful.

In spite of the desperate condition of many of these patients, there were many unexpected recoveries. One patient, at whose operation Captain Archer had assisted while serving in the operating room, had fractured ribs, perforations of the pleura and diaphragm, and several intra-abdominal injuries. After definitive surgery he was given little chance for survival. Several days later, while reading films, Captain Archer recognized this patient's name and learned that he was making a smooth recovery.

By the end of December 1941, most of the seriously wounded casualties had been evacuated to the mainland. The Army losses, which were small in comparison with Navy losses, were 229 killed and 459 wounded, 113 seriously. Most of the Army casualties were from Hickam Field. Of the severely wounded, only eight returned to duty in the Hawaiian Department.

CHAPTER XXI

Buildup of Hospital Facilities

Richard C. Boyer, M.D.

TRIPLER GENERAL HOSPITAL

At the time of Pearl Harbor, Tripler General Hospital (later the 218th General Hospital), Honolulu, T.H., had a bed capacity of about 830. By the end of 1943, its capacity had expanded to 2,000 beds, which it maintained until the end of the war. Some expansion beyond this number was possible. Tripler was the most active medical center in the Hawaiian Department and was an excellent training center for both officers and enlisted men because of its strategic position in the heart of military activities, the very rapid expansion of its bed capacity, and its medical experience in the first phase of the war.

Tripler General Hospital also had a very active outpatient service for both military and attached civilian personnel. In 1942, there were about 16,000 outpatients and 9,082 hospital admissions. In 1944, the respective figures were 55,743 outpatients and 19,146 hospital admissions. The availability of specialized services with qualified personnel in practically every field of medicine accounted for the activity of the outpatient department.

Radiology

At the time of Pearl Harbor, the X-ray department of the hospital was under the direction of Lt. Col. (later Col.) John D. Barnwell, MC, whose Army experience covered about 23 years and who had had special training at the University Hospital in Ann Arbor, Mich., and at the Mayo Clinic. Events were to prove him an excellent instructor in both diagnostic radiography and radiation therapy.

His assistant, Capt. (later Lt. Col.) Maurice C. Archer, MC, had reached Hawaii in May 1941. There were seven technicians in the department, and a stenographer. When Colonel Barnwell's work as radiologic consultant for the Central Pacific Area (p. 518) kept him away from the hospital for increasingly long periods, Captain Archer acted as chief of the X-ray service.

Lt. Col. (later Col.) Leslie M. Garrett, MC, headed the department from June 1943 until the end of the year, with Maj. (later Lt. Col.) Wolcott E. Buren, MC, who had been in training in the department since February 1943,

as assistant chief. Capt. Abraham R. Koransky, MC, a dermatologist who adapted quickly to radiology, was assigned to the department in April 1944. In addition to his other duties, this officer supervised the X-ray department at Provisional Hospital No. 4 at Kaneohe, Oahu, T.H. 1st Lt. (later Capt.) Murray Reswick, MC, who had had some previous radiologic training, was assigned in October 1944; later he had charge of the chest X-ray unit at the Army induction station in Honolulu.

The equipment at Tripler General Hospital at the time of Pearl Harbor consisted of three 200-ma. X-ray machines; a portable machine; machines for superficial and deep therapy, the latter a 200-kv. General Electric unit; and all necessary accessories. The darkroom was adequate.

Additional equipment was procured as the hospital expanded. The Eastman Kodak Co., anticipating possible future needs, had stored two General Electric 200-ma. machines, which they turned over to the hospital at once. Mr. Smith Pratt, of Kodak Hawaii, Ltd., Honolulu, resurrected some old fluoroscopic units that had been used in World War I and put them into working condition. He was also able to rig up a machine for superficial radiation therapy from parts of old Keleket (formerly Kelly-Koett), Standard, and General Electric machines. This machine was calibrated with a Victoreen r-meter and proved quite useful.

The volume of work in the X-ray department of the hospital increased as the war progressed. In 1942, its personnel made 14,333 diagnostic examinations and administered therapy to 794 patients. In 1944, the respective figures were 26,650 and 1,106. Of these patients, 11,152 attended the outpatient clinics.

SCHOFIELD BARRACKS STATION HOSPITAL

The station hospital at Schofield Barracks, Oahu (later known as the North Sector General Hospital and still later as the 219th General Hospital), occupied a central location on the Army Post at Schofield Barracks, about 15 miles inland and northwest of Pearl Harbor. It received its first casualty 8 minutes after the attack.

After Pearl Harbor, this hospital expanded along the same lines as Tripler General Hospital. At the end of 1941, its bed capacity was 422 and its potential emergency expansion was 1,782. At the end of 1943, the bed capacity was 2,000, which was maintained until the end of the war.

Radiology

The chief of the X-ray service in December 1941 was Maj. (later Col.) Edward M. DeYoung, MC, a trained radiologist. In May 1943, he was succeeded by Maj. (later Lt. Col.) Richard C. Boyer, MC, who served until October 1945, with Capt. Ralph Friedman, MC, as his assistant. During 1944, the staff of technicians averaged 12, and there was 1 civilian stenographer.

The department was equipped with two heavy-duty General Electric machines, neither of which was shockproof; two mobile units; and a table for genitourinary diagnostic work. Eventually this hospital had four 200-ma. machines for diagnostic work, one of which had a spot-filming device; three portable units; a cystoscopic unit; and machines for superficial and deep therapy. The only machine in the Central Pacific Area for deep X-ray therapy, a 200-kv. General Electric unit, was received in this hospital in August 1942.

The X-ray equipment in this hospital was never adequate to the workload, chiefly because general shortages did not permit replacement of machines that were not completely shockproof for diagnosis and superficial therapy.

This radiology department carried an increasingly heavy load as the war progressed. The hospital admitted 17,996 patients in 1943 and 17,274 in 1944, but in 1944, its outpatient load from surrounding dispensaries and other installations was 38,577. In 1943, there were 26,083 diagnostic X-ray examinations, and in 1944, 27,441. In 1944, a total of 630 patients received 2,489 superficial X-ray treatments, and 38 patients received 105 deep X-ray treatments. A very active dermatology clinic referred most of the patients for superficial therapy, chiefly for dermatophytoses and plantar warts.

OTHER HOSPITALS

Hickam Field Station Hospital

The small station hospital at Hickam Field on Oahu remained intact during the attack on Pearl Harbor, and casualties were received within 11 minutes after the initial bombing. At this time, the hospital had a single 100-ma. diagnostic unit. During the war, it was maintained, without additional X-ray equipment, as a small station hospital, chiefly for Air Forces personnel.

Provisional Hospitals

Plans made before Pearl Harbor to expand hospital facilities on Oahu had included the establishment of a number of provisional hospitals, the first of which was set up the day of the attack. Within the next 6 days, all were put into operation. As numbered general hospitals arrived in Hawaii, they took over these provisional hospitals, all of which had adequate X-ray departments.

Provisional Hospital No. 2, which became the 147th General Hospital on 22 June 1942, was perhaps the most active of these hospitals. Its original bed capacity of 215 had increased by 1,000 by the end of 1942 and eventually reached 1,500.

The X-ray department of this hospital began to operate on 1 September 1942, with Maj. (later Lt. Col.) Leland F. Glaser, MC, as head of the service.

He had a part-time assistant, and usually had four or five trained technicians, with three or four others in training.

The department originally had a single 200-ma. General Electric machine, with all the necessary accessory equipment. Later, as the work expanded, the department operated as two separate units, with additional equipment consisting of a Philips 100-ma. machine mounted on a genitourinary table; a Picker field machine; a generator; and a table and mobile stand. Still later, another 200-ma. General Electric unit and a Picker portable unit were secured. In 1943, this department made 11,086 diagnostic examinations and in 1944, 16,379. Almost 600 of the patients examined in 1944 were military and civilian outpatients. In 1943, the department gave 215 superficial therapy treatments with the Picker portable unit. In 1944, 311 patients received 872 treatments.

Hospitals on Other Islands

At the onset of World War II, there were very few Army medical facilities in the Hawaiian Islands except on Oahu. Almost at once, existing structures were converted to hospital use and new construction was begun, so that by March 1942, when station hospitals began to arrive from the Zone of Interior, they could set up at once. The medical installations on these islands were often remote and isolated, but the islands served as training and staging areas for the troops destined for combat farther out in the Pacific and their medical requirements had to be met.

Radiologic service was generally adequate in these hospitals in respect to both personnel and equipment, though fluctuations in the powerlines sometimes produced difficulties.

The workload was frequently heavy, as the experience of the 22d Station Hospital on Maui showed. The department was in charge of Captain Boyer, who was assisted by three trained technicians.

Equipment consisted of an Army field unit, later replaced by a 200-ma. General Electric unit with over-and-under radiographic-fluoroscopic tube; a portable unit purchased locally; and a small darkroom, equipped with a dryer and with locally constructed developing tanks. Between 19 April and 31 December 1942, this department performed 3,229 diagnostic examinations. In October 1942, after a field unit had been calibrated with a Victoreen r-meter obtained from Tripler General Hospital, superficial radiation therapy was administered to 37 patients.

CHAPTER XXII

Administrative and Logistic Considerations

Richard C. Boyer, M.D.

CONSULTANTS IN RADIOLOGY

Throughout the war the Office of the Area Surgeon, located at Fort Shafter, Oahu, T.H., maintained a consultant in radiology on the headquarters staff. It was never possible, however, to make this a full-time position because of the serious shortage of trained radiologists in the area. This was unfortunate. A full-time appointment became increasingly desirable as the magnitude of the military operations increased and the consultant had to travel more and more widely to carry out his duties in forward areas.

Lt. Col. (later Col.) John D. Barnwell, MC, was appointed Consultant in Radiology for the Hawaiian Department (later the Central Pacific Area) shortly after Pearl Harbor. At the same time, he continued to serve as Chief of Radiology at Tripler General Hospital, Honolulu, T.H. When he returned to the mainland in June 1942, he was succeeded by Lt. Col. (later Col.) Edward M. DeYoung, MC, who performed his consultant's duties in addition to his work as Chief of Radiology at the station hospital at Schofield Barracks, Oahu, T.H.

When Colonel DeYoung was assigned to the Zone of Interior in May 1943, he was succeeded by Lt. Col. (later Col.) Leslie M. Garrett, MC, who served as Consultant in Radiology, Central Pacific Area, and as Chief of Radiology at Tripler General Hospital until the end of the war.[1]

Functions

Colonel Barnwell was responsible for the organization and construction of X-ray facilities in the hospitals on the Hawaiian Islands other than those already in existence (Tripler General Hospital and the hospital at Schofield Barracks) at the time of Pearl Harbor. By the spring of 1942, 12 departments of radiology were essentially ready for operation on the five main islands. In place of commercial developing tanks, which were not available, Colonel Barnwell supervised the construction of several tanks made of redwood planking. They held up remarkably well during the war.

[1] Much of the material in this chapter is derived from the report to the Area Surgeon prepared by Colonel Garrett at the end of his tour of duty.

Colonel Barnwell also inventoried both Army and civilian X-ray equipment available on the islands after the opening of hostilities. With this inventory on hand, it was possible to accomplish a wise distribution of the meager radiologic equipment and supplies in Army hospitals and to purchase supplementary equipment from local civilian supply houses and from hospitals and dispensaries.

Finally, as Consultant in Radiology, Colonel Barnwell made a number of tours of inspection of the medical facilities on the Hawaiian Islands.

The consultants who succeeded him had the same problems—chiefly deficiencies in equipment and shortages of trained radiologists, technicians, and repairmen—and they carried out the same functions, including inspection trips to other islands.

PROFESSIONAL RADIOLOGIC PERSONNEL

When Pearl Harbor was attacked, Colonel Barnwell at Tripler General Hospital and Colonel DeYoung at the Schofield Barracks Station Hospital were the only trained Regular Army radiologists in the Hawaiian Department. By the summer of 1942, five additional radiologists had arrived with numbered general and station hospitals; they were assigned to the islands of Hawaii, Maui, and Kauai.

All through the war, trained radiologists were assigned to the general hospitals (of which there were six by 1945) in the Central Pacific Area, including those that participated in the Ryukyus campaign. There was also a trained or partly trained radiologist in each of the 21 station hospitals in the area, at least most of the time.

Training.—Whenever a medical officer with some radiologic training was not available, the commanding officer of the hospital, with the help of the Office of the Surgeon and the advice of the Consultant in Radiology, made every effort to provide training for the untrained officer assigned to the service. Training usually took the form of an intensive short course in the essentials of Army radiology and the use of field X-ray equipment. Hospital training was given at Tripler General Hospital and field training at the special field training center at Koko Head, Oahu.

Medical officers whose training in radiology was limited or who had had no training beyond a short course in one of the schools in the United States (p. 30) were given additional practical training at Tripler General Hospital. Some 10 officers, most of whom later served as chiefs of radiology, were given this type of training.

TECHNICIANS

Trained radiologic technicians were in as short supply as were radiologic officers at the beginning of the war. Many of the trained technicians in the

Hawaiian Department departed to officer candidate schools in the Zone of Interior shortly after Pearl Harbor, while over the same period, only a few trained technicians were received from Army schools on the mainland.

The demand for, and turnover of, X-ray technicians were constantly recurring problems throughout the war at all the hospitals in the area. In 1944, for instance, the X-ray department at Tripler General Hospital lost seven trained technicians by transfer. Their transfer was unavoidable; they were needed in newly arrived units or in units designated for combat. A fair number of replacements were received from the mainland, with a sound basic knowledge acquired at the training schools in the Zone of Interior, and most of them quickly adapted themselves to the local situation. More often, however, the only answer to requests for replacements was "Train your own."

Training.—This was exactly what was done. Training programs for technicians were set up in the X-ray departments at Tripler General Hospital, the hospital at Schofield Barracks, the 147th, 204th, and 219th General Hospitals, and, from time to time, other hospitals. The school at Tripler was started in 1943; 31 technicians were trained that year and 28 the following year. Six technicians were trained at the 204th General Hospital in 1943 and five at the Schofield Barracks Station Hospital. Sometimes as many as 20 to 30 technicians were in training at once in the hospitals in the Hawaiian Department.

The training courses averaged 6 weeks, but sometimes, depending upon the demands of the combat situation and the aptitude of the trainees, they were shorter. In some situations they were extended to 7 months. While both didactic and technical training was provided, didactic instruction was limited. The principal teaching technique was on-the-job training, secured by working with experienced technicians under the supervision of radiologic officers. Use of field equipment was emphasized, for many of those in training would eventually be assigned to X-ray departments in units in the combat zone.

Functions.—In the Hawaiian area, the larger general hospitals were able to hire civilian secretaries (as well as, occasionally, civilian technicians). As a rule, however, X-ray technicians had to perform both clerical and darkroom duties, as tables of organization did not provide for clerks, medical stenographers, or darkroom assistants.

In the forward areas, especially during or soon after combat operations, radiologists and X-ray technicians assigned to mobile hospital units or other field type hospitals had to exercise a high degree of dexterity and ingenuity in transporting, setting up, and operating Army field X-ray equipment. Improvisation to meet special needs in special situations was, in fact, often the keystone of the successful operation of an X-ray department in the field or at a newly garrisoned base.

SERVICE TECHNICIANS

A type of technician sorely needed in the Central Pacific Area on radiologic services was one with a knowledge of installation, maintenance, and repair of X-ray machines . During the whole war, only a few men with this kind of training were available, and radiologists and technicians often had to act as their own troubleshooters. In Honolulu, Mr. Edward Hartzler, of Wadsworth Photographic Supply, and Mr. Smith Pratt, of Kodak Hawaii, Ltd., were extremely helpful throughout the war.

EQUIPMENT

Shortages of equipment and the necessity of using nonstandard and outmoded equipment caused many radiologic difficulties in the Central Pacific Area. There was never enough, and what was available was generally overtaxed. In a busy X-ray department, limited tube capacity required many improvisations for satisfactory service. Some of the equipment at Schofield Barracks Station Hospital, for instance, had open overhead cables and Coolidge tubes with lead glass enclosures. The war was almost over when this equipment was replaced.

In the first days of the war, there was a frantic effort to expand existing X-ray facilities. Both used and new equipment was purchased from local supply houses in Honolulu, from the dispensaries of sugar plantations, and from civilian hospitals that could spare it. Some of this equipment was used throughout the war. Colonel Barnwell and Colonel DeYoung, the Consultants in Radiology, reported that an attempt to put into use obsolete 1918 Scherer models was abandoned as impractical.

The large general hospitals and many of the station hospitals in the Hawaiian Islands were furnished with conventional diagnostic units manufactured in the United States, but there were multiple models, and problems of maintenance and service, difficult enough as just noted, would have been greatly simplified if all the units had been of one make or if the parts could have been standardized.

The workhorse in forward and small hospitals was the field X-ray machine (item 91085). It performed superbly under all sorts of difficult physical and climatic conditions, including high humidity, extreme heat, exposure to sea water, rust, rough handling, and operation by untrained and inexperienced technicians. The only serious defect that recurred with any frequency was puncturing of the high-tension cables. The extreme humidity of the whole area was detrimental to these cables, and the waterproofing kit furnished to correct the trouble did not prove effective. A research project to overcome the defect was undertaken in the Office of The Surgeon General, but the war ended before new cables were received in the Central Pacific Area.

The field X-ray table (item 96145) was also a sturdy and satisfactory piece of equipment. Most radiologists thought that the addition of a moving grid,

which it lacked, would have been a great improvement. The device on this table for the localization of foreign bodies was never used extensively. Surgeons were simply not interested in this piece of equipment. The Sweet eye localizer, however, was used to good advantage.

Only a few of the fluoroscopes were provided with commercial spot-filming devices. Their absence was a serious handicap in a fixed hospital that did any volume of fluoroscopic work. Several radiologists improvised such attachments for their units.

Late in the war, Tripler General Hospital received the single rotating anode X-ray tube sent to the Central Pacific Area. When the war ended, a few hospitals in forward areas had been equipped with medium- or heavy-duty machines of U.S. manufacture, and plans were underway to equip all fixed hospitals in the area with them.

It would have been highly desirable for all X-ray departments to be provided with wafer grids as well as portable Bucky grids, but they were not available during the war. Many accessory items, such as stereoscopes, film driers, view boxes, angle boards, and chest cassette racks were improvised and constructed locally when they could not be secured through supply channels.

The field processing units, auxiliary wash tanks, and film driers performed valiantly in the Central Pacific Area, in spite of the frequent difficulties caused by the hot, humid climate and shortages of fresh water. The field electrical generator gave excellent service with a single exception: A certain number had defective governors when they were first put into use, and, under conditions of high temperature, they would overheat after an hour and a half of use. In busy installations, in which more than one generator was usually available, it was found best to use them alternately.

Most of the equipment sent to the area was packed satisfactorily, though there was some breakage of rectified tubes and fittings on the shockproof tables.

FILMS

Supply

Diagnostic X-ray examinations were made in so many cases throughout the war in the Central Pacific Area that there was scarcely a time when films were not in short supply. In some installations in the combat zone, as many as 80 percent of the patients admitted were examined radiographically.

The extreme shortages of films immediately after Pearl Harbor were partly overcome by the action of Kodak Hawaii, Ltd., of Honolulu, which issued films to military units simply on demand. The situation remained critical, however, for the next 2 years. In May 1943, the Surgeon, Hawaiian Department, issued a directive to all hospitals to reduce their usage of film by 25 percent or more and warned that a 50-percent cut might be necessary

later because of shortages in the Zone of Interior. In June 1943, a second directive was issued, detailing methods of conserving films, such as reducing the number of views and cutting films into various sizes and lengths to accommodate the part being examined. The Consultant in Radiology maintained a monthly check on the usage of films, and the original rate of use was consistently decreased by 30 to 50 percent for the remainder of the war.

An expedient that accomplished a considerable saving of film was the construction of a mobile photofluorographic unit for taking chest films. It was constructed under the supervision of Colonel DeYoung, then the Consultant in Radiology, with the considerable help of Capt. Murray Reswick, MC, and was put into use in February 1945. During the next 8 months it was used on 14,052 inductees and 4,700 prisoners of war in the Hawaiian Islands.

Deterioration

Metal containers for films were discontinued early in the war. The paraffin wrappers that replaced them were not satisfactory, but the waterproof paper covering introduced later proved much more efficient.

Under tropical conditions, films deteriorated very rapidly, even when they were shipped and stored in hermetically sealed metal containers. Films not so protected or actually mishandled (p. 530) spoiled even more rapidly. Whenever possible, films were stored under refrigeration.

Constant testing of film stocks was necessary because of film fog. Whenever it was detected, all batches of that expiration date were immediately issued and were used before they became useless. The best solution of this particular problem was frequent shipments of small quantities of films.

Processing

As pointed out elsewhere, the processing of films presented special difficulties in all Pacific Ocean Areas. In the Hawaiian Islands, the problems were minor because of the milder climate and the adequate supply of cool water for the processing tanks. On most of the other islands, the extreme heat and humidity and the limited water supply confronted the radiologic personnel with a trying situation.

Films could never be left in cassettes; they would soften and stick to the screens. The heat was often so intense in the darkroom that it was almost impossible to keep the solution in the processing tanks even reasonably cool. In one instance on Kwajalein, the temperature in the darkroom tent rose to 130° F. during the day, and even when the cooling unit was run continuously, the temperature of the processing solution could not be reduced below 90° F. Placing the darkroom tent inside of another tent or in a building sometimes improved matters. Fluoroscopy was frequently done outside at night, and films were also developed at night if they were not needed immediately.

With the limited water supply on many of the Central Pacific islands, it was not possible to wash films by the standards one would employ in civilian practice. The small amounts of fresh water available had to be used as skillfully and sparingly as possible. Often, fresh water was saved for the final washing, the preliminary washing being done with brackish water.

Handling of Films

As the war progressed and lines of evacuation became well established, particularly in the intermediate zone, it became the general practice for films to be sent with the patient and his record as he moved to the rear. This policy had two advantages: It conserved films because unnecessary repetitions of examinations were avoided, and it decreased the patient's exposure to radiation.

PROTECTION OF PERSONNEL

From the standpoint of protection of radiologic personnel, the most serious problem was the shortage of lead. Engineers were usually able to furnish the amounts necessary to protect walls and control booths properly in the hospitals that were constructed in the Hawaiian Islands. In forward areas, however, lead sheeting was provided in only very small amounts, sometimes not more than a few square feet. This deficit was met in various ways. Such lead as was available was used for screens behind which the technicians could stand. They were instructed to stand well away from the patients. Lead-impregnated aprons and gloves were worn routinely. Setting of fractures and search for foreign bodies under the fluoroscope were held to a minimum. In one hospital on Saipan, a 4-inch layer of sand was used between plywood walls as a substitute for lead.

In 1944, under the direct supervision of Colonel Garrett, then Consultant in Radiology, a detailed investigation of the effectiveness of the protective measures then in use was made on the Hawaiian Islands, the survey covering practically every installation in the area. Dental films were attached to the clothing of all radiologic personnel for periods of a week, and the Geiger counter was used for spot checking. A Victoreen r-meter was also used for calibration of the machines employed for therapy. It was found that dental X-ray technicians received considerably more exposure than the other technicians, but in none of the installations was any overexposure of personnel detected.

When War Department Technicial Bulletin (TB MED) 62, published 1 July 1944 and covering the subject of X-ray protection, was received in the Central Pacific Area, another check was made of all the hospitals in the area, and written recommendations were made by the Consultant in Radiology for the correction of deficiencies identified by the criteria laid down in

this bulletin. Particularly in the forward areas, however, shortages of lead continued, and the optimum standards simply could not be met in many hospitals. In these installations, special emphasis was put upon periodic blood counts and upon the limitation of working hours as recommended in this bulletin.

CHAPTER XXIII

Radiologic Activities in Combat Areas

Richard C. Boyer, M.D.

THE ISLAND CAMPAIGNS

It was almost 2 years after the attack on Pearl Harbor that the first attack was launched against the Japanese, by amphibious forces of the Central Pacific Area. The Gilbert and Marshall Islands were the first targets. Landings were made simultaneously at Tarawa and Makin Atolls in the Gilberts on 20 November 1943. In the Marshall Islands, Kwajalein and Eniwetok were invaded early in 1944, followed, in June and July, by Saipan, Guam, and Tinian in the Marianas (map 3, p. 498).

The Palau Island Group represented the last main obstacle in the Central Pacific Area on the way to the Philippines. This operation, Stalemate II of the Western Pacific campaign, began in these islands on 15 September and ended on 1 December 1944. The Iwo Jima operation in February and March 1945, which was aimed at Japan itself, was a Navy-Marine operation, but Army hospitals, particularly in the Marianas, handled a large number of the almost 20,000 wounded-in-action casualties.

Pattern of Medical Care

During actual combat on the small islands in the Gilbert and Marshall Groups, there was little or no attempt to set up hospital facilities ashore, and no radiologic service was provided. In these amphibious operations, the medical units that provided emergency care landed on the beaches with the combat troops, or came ashore shortly afterward. Their mission was to administer emergency medical treatment, treat shock, splint fractures, and evacuate the wounded to the beaches.

From the beaches, the wounded were carried by small landing craft, often through treacherous reefs, to hospital ships or other transports standing offshore. These ships functioned, in effect, as field or evacuation hospitals. X-ray facilities on the ships, while adequate, were frequently overtaxed.

Evacuation by ship to Oahu required from 4 to 10 days. Here the wounded were distributed among the general hospitals. As a rule, the Navy did not send records and films with the patients; ordinarily, they did not arrive until several days after the patients had been received. Repeat

X-ray examinations were therefore made on Oahu as the patients were taken to their wards, or shortly thereafter.

From a medical standpoint, the second phase of atoll warfare was the establishment of facilities for garrison forces, including provision for radiologic examinations. Field X-ray equipment usually functioned well in these conditions, but the extreme heat, combined with water shortages, often posed problems in the handling and processing of films and required on-the-spot improvisation.

The pattern of medical care, including radiologic care, was essentially the same on all the island groups on which attacks were subsequently made on the way back to Japan.

Garrison Phase

During the garrison phase of the island campaigns, considerable X-ray service was provided. At the 1st Station Hospital in the Gilberts, for instance, although supplies of film were limited and only essential examinations were made, 1,687 examinations were made over a 7-month period, including a number of intravenous pyelograms and a number of barium studies of the gastrointestinal tract.

During the 6-week period the same hospital was on Kwajalein, where it was set up on pallets under a pyramidal tent, the X-ray department made 215 examinations, chiefly for the diagnosis of fractures, dislocations, and retained foreign bodies. The X-ray department of Provisional Hospital No. 2, which took over medical care during the garrison phase, operated in a quonset hut and used field equipment. The field darkroom tent, which was set up within the hut, was unbearably hot—the temperature rising to 120° to 130° F., during the day. The field refrigerating unit did not cool the developing solution in these circumstances, and the tent within the quonset hut was replaced by a plywood room. By using fans and working during the cooler parts of the day, the department technicians were able to produce satisfactory radiographs. Processing solutions were made from distilled drinking water, and it was found that films could be washed in salt water without damaging them.

Before Kwajalein was occupied, Provisional Hospital No. 2 had been stationed on Carlos Island, with its chief mission the care of natives. Its radiologist, Capt. Homer V. Hedges, MC, fluoroscoped 112 patients in the first few days of hospital operation, using field equipment. He found no tuberculosis or other pulmonary disease but observed two interesting phenomena, globular cardiac shadows and bone lesions that seemed to resemble those of yaws (p. 641).

On Saipan, the X-ray department of the 369th Station Hospital, in charge of Capt. (later Maj.) Ted F. Leigh, MC, performed 3,695 examinations between July and December 1944. Captain Leigh was assisted by eight technicians and two secretaries. Fluoroscopy was used to localize foreign bodies.

It was on Saipan that radiologists and technicians had their first opportunity in the Central Pacific Area to put field X-ray equipment to a major test in combat (figs. 180 and 181). The long months of study and practice under simulated field conditions were rewarded by the generally satisfactory performance of the machines and other items of equipment under trying circumstances and a heavy casualty load. There were not many complaints, though the 31st Field Hospital, in its 1944 report, mentioned frequent breakdowns of the field generators (2.5 kv.-a).

All of the early operations of the hospitals on Guam were hampered by poor timing in the landing of equipment, water damage, and loss of supplies by looting. X-ray equipment was slow in getting ashore, and much of it was stolen or otherwise lost.

THE RYUKYUS CAMPAIGN

The final battle for the Central Pacific Area was also the fiercest. It took place in the Ryukyus, chiefly on Okinawa. The attack began on 1 April 1945, and the island was not considered secured until 25 June 1945. Battle and nonbattle casualties amounted to more than 35 percent of the participating forces, which made the Okinawa campaign, in proportion to troops engaged, one of the costliest of the whole war.

The pattern of wounds on Okinawa was somewhat different from the pattern elsewhere in the Pacific because the Japanese used artillery extensively. The pattern of evacuation was also somewhat different because the beaches were not heavily defended by the enemy.

Total medical personnel committed to Okinawa during the combat and garrison phases of the campaign numbered about 10,000. For the most part, the units involved had had previous combat duty or had the benefit of instruction and training based on previous experiences in the Central Pacific Area.

Hospital reports contain little direct information about X-ray facilities and personnel, but it can be assumed that portable X-ray apparatus was set up shortly after field hospitals landed and that numerous radiographs were taken in them. Maj. John W. Devine, Jr., MC, and Capt. (later Maj.) Hollon W. Farr, MC, who served on a neurosurgical team from 2 April to 22 June 1945, reported that all their patients were X-rayed routinely, as soon as they were out of shock, on their way to the operating room tent (*1*).

Since there were not enough radiologists to staff all field hospitals, the radiographs were usually made by technicians and interpreted by the surgeons who were to perform the operations. Improvised view boxes were set up in the operating rooms, and the films were often used while they were still wet. The availability of X-ray facilities in close proximity to the battlefield contributed to the care that the casualties on Okinawa received and that was regarded as the best yet achieved in the Central Pacific Area.

FIGURE 180.—Technicians preparing to X-ray injured leg of combat casualty in field hospital on Saipan, 1944.

SPECIAL EXPERIENCES

75th Station Hospital

The work of one station hospital on Okinawa, the 750-bed 75th Station Hospital, which may be considered typical, was described by Capt. (later Maj.) Carroll Brown, MC, the radiologist, in a letter written in 1959. This hospital set up on 20 June 1945, and received casualties during the final phase of the campaign, chiefly nonbattle casualties from adjacent military units. After the war in the Pacific ended, many natives admitted were in poor condition from such diseases as tuberculosis, dysentery, and beri beri. Superficial X-ray therapy was used for numerous dermatologic conditions.

When the hospital landed, the island was supposed to be secured, which it was, in the sense that there was no organized resistance. Some of the enemy, however, were still hiding in caves and emerged periodically in search of

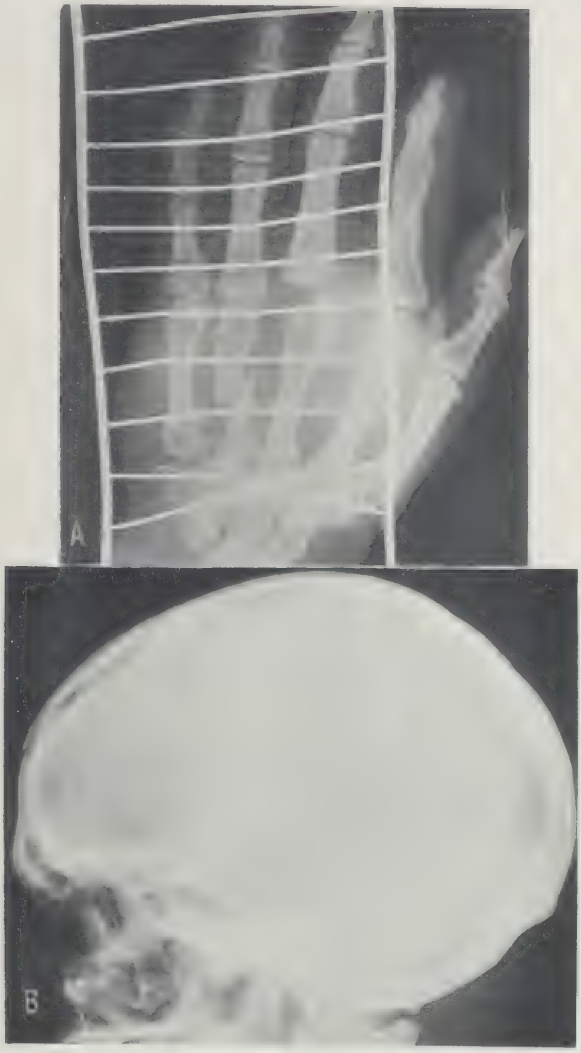


FIGURE 181.—Wounds made by Japanese in hand-to-hand combat on Saipan. A. Roentgenogram of left hand showing wound made by Japanese cutting weapon, involving bones in metacarpal area. B. Roentgenogram of skull showing cutting wound of frontal bone. Note flap-like bony fragments.

food. This situation kept medical personnel within the bounds of the camp. Occasional air raids also required blackouts.

Major Brown was assisted by seven enlisted men. His X-ray equipment was originally set up in a tent, but in October 1945 it was moved into quonset huts. It consisted of three field X-ray units, two for general work, and one,

installed in a darkroom, for fluoroscopy. Gastrointestinal studies were carried out with an improvised spot device. For the first 2 weeks the department operated with power obtained from two portable gasoline generators; then the hospital secured a central generating plant. The equipment gave very little trouble except for the burning out of several cables. A field processing tank was used in the darkroom. There was no running water, and the water in the tank was recirculated.

233d General Hospital

The radiologic experience of the 233d General Hospital on Okinawa was described in detail by Lt. Col. (later Col.) Joseph Levitin, MC, chief of the radiology service, who was assisted by Capt. Nicholas G. Demy, MC, and who was succeeded by Lt. Col. John F. Miller, MC.

Colonel Levitin was assigned to the 233d General Hospital on 23 January 1945, in Hawaii, where it was generally understood that the hospital would go to a forward area in the Central Pacific Area, probably in the Ryukyus. As head of the department of radiology, he attempted to find out what equipment was in storage for it, so that he could inventory it and requisition what was lacking. He was unsuccessful in this attempt.

When the ship on which the hospital was to be transported was being loaded, Colonel Levitin discovered that the X-ray films were to be carried on deck, without cover. The Navy loading officer could not be convinced that this was not the way to handle films. To him, they represented a fire hazard, and the only safe place for a fire hazard was on deck.

It took 6 weeks for the convoy to reach Okinawa, partly because of long delays at Eniwetok and Ulithi. During this time, the films on deck were exposed to tropical sun and frequent, heavy rains. When the hospital finally landed on Okinawa, the films, along with other equipment, were stored on the beach, and no amount of protest could induce the supply officer to protect them. Unloading officers, like loading officers, regarded X-ray films as well down the list of priorities. Very little alcohol was lost, however, because, on the advice of those who were more experienced, all the bottles containing it were relabeled as medication for external use only.

The location assigned to the hospital was directly across the road from an ammunition dump, which was contrary to regulations governing the selection of hospital sites. A protest to Command resulted in the decision that, as directed, the hospital should be set up on the site indicated, which was a sweet potato field, covered over with abandoned equipment, knocked out tanks, and overturned trucks. The only structure standing in the vicinity was an abandoned schoolhouse.

X-ray facilities consisted of two large ward tents and a smaller tent to be used for a darkroom as well as for fluoroscopic examination. It was provided with black drapes and had a double entrance curtain. The only

provision for cooling this tent was a small electric fan about the size of a hair drier. The humidity was high, and the heat in the tent was intolerable.

One ward tent was set aside for radiography. The other was used for a viewing and consultation room and for files. Since no lead sheathing was available, rows of sandbags were used between the radiographic tables to protect the operators.

The darkroom area was set up as a separate unit, about 20 feet from the radiographic tent. The sides were lined with sandbags and the roof was made of a double canvas top, scrounged [1] from discarded tents. The black-drape issue tent was cut up and served as an entrance maze. Fans taken from wrecked tanks on the Shuri battlefield were set up at one end of this area and were directed to blow over a desert cooler, operated by dripping water over woodchips and straw. This improvised darkroom was both cool and lightproof. During blackouts, the darkroom could be lighted, permitting the X-ray personnel to read, play bridge, or otherwise occupy themselves.

The developing tank was made from a fuel tank removed from a wrecked plane; a 2-inch length of hose from a Japanese firetruck fed water into it. One bypass dripped water on the desert cooler. Rainwater, caught in tent flaps, supplemented the supply of water hauled in by trucks; all water on the island was obtained from wells.

Tabletops, chairs, files, and a bridge table (highly important for morale) were constructed of wood from packing cases. Plywood was not available for many months.

All of this work was done without carpenter tools except for the occasional hammers and hatchets some foresighted individuals had brought along with them. Every nail removed from packing cases was straightened and re-used.

A fluoroscopic room was not set up. It was decided, instead, to make fluoroscopic examinations at night. Very few were made. There was no point to making gastrointestinal studies of a suspected ucler, for instance; if it had been identified, there was no diet with which to treat the patient. It was more efficient, once the diagnosis had been made clinically, to send the man back to Oahu, where he could secure proper treatment.

Five gasoline-driven field generators provided current for the department. Other equipment consisted of five portable 30-ma. 100-kv. X-ray units and five frames of radiographic tables with fluoroscopic screens. The stereoscopic chest cassette changer was a large and useless piece of equipment, its greatest value being the boards of the cases in which it was packed.

Occasional communications received from the mainland criticized the quality of the radiographs that accompanied patients back from Okinawa, the chief complaint being that they were not adequately washed, so that, by the time they reached Zone of Interior hospitals, they were not diagnostic.

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[1] Scrounge was a vernacular word in general usage, which meant a combination of scavenge, take, steal, or procure by any other means without being apprehended.—A.L.A.

Along with the complaints came instructions as to how long films should be washed and the number of gallons of running water of the proper temperature that should be used per square foot of film. The writers evidently had no concept of radiology in the field. On Okinawa, as already mentioned, all water was well water, and all water for the entire hospital, including that for personal use and for laundry, had to be hauled in by truck. Only a limited amount was allotted to the X-ray section. To wash films as directed by these critics would have used up a complete truckload. By catching rainwater, a fair supply of extra water was obtained, enough to rinse the films but never enough to wash them adequately. The department had a developing tank, but it had no plumbing fittings to connect with a water supply—if there had been a water supply. Pipes, faucets, and valves were not included in the hospital table of equipment and were not obtainable on Okinawa.

The 233d General Hospital never functioned as more than a station hospital. Field hospitals and dispensaries sent patients to it with such complaints as low back pain for evaluation. The only flurry of interesting cases came when Allied prisoners of war were received. Repatriated U.S. prisoners who were brought to Okinawa were then flown directly to the Zone of Interior. English, Australian, New Zealand, and Dutch prisoners were X-rayed, and a large amount of advanced tuberculosis was found among them.

Maj. (later Lt. Col.) Harvey G. Taylor, MC, in charge of Military Government on Okinawa, asked for diagnostic assistance when an outbreak of what native physicians called Japanese encephalitis occurred among the civilian population. Twelve children with this condition were placed in an isolation ward and examined with a portable unit. Some had pneumonia and one had bacterial endocarditis, but it was doubted that any of them had true encephalitis, although an outbreak of this disease did occur. At Major Taylor's request, chest films were also taken of native school children. The portable unit was used, and a portable darkroom was set up for processing the films. The only significant finding was calcified nodes.

The radiologists at the 233d General Hospital organized an X-ray study club on Okinawa. It was an interesting diversion to meet other radiologists from the Army and Navy—some of them radiologists only by order of the Army and Navy—and it was useful to discuss individual problems. A naval officer, for instance, could not reduce the temperature of the water in his darkroom tent, though he was fortunate enough to have a storage water tank and piped running water. A visit to his hospital showed that the trouble was in the location of the pipes which lay on the ground exposed to the direct rays of the sun.

Most of the radiologists had only routine survey radiographs to exhibit, but one, who had examined Japanese prisoners of war, had interesting cases of empyema, osteomyelitis, and other conditions.

The 233d General Hospital was in process of expanding to 2,000 beds for the invasion of Japan when V–J Day came. Then, when there was no longer

need or use for it, the X-ray department was suddenly deluged with equipment, most of it from Navy installations, including 200- and 300-ma. General Electric Bucky tables and everything else a radiologist could wish for.

REFERENCE

1. Devine, J. W., Jr., and Farr, H. W.: Neurosurgical Management of Wounded in Okinawa Campaign. Mil. Surgeon 103: 202–207, September 1948.

CHAPTER XXIV

Clinical Considerations

Richard C. Boyer, M.D.

DIAGNOSTIC RADIOLOGY

In view of the shortage of qualified radiologists in the Central Pacific Area throughout the war, it was fortunate that the field of military clinical radiology was limited. That is, the majority of the patients who required examination were young (or, much less often, middle-aged) adults who were usually healthy. The more complicated radiologic problems of the very young and the older age groups were seldom encountered. Moreover, diagnosis usually concerned trauma—fractures, dislocations, soft-tissue injuries with or without retained foreign bodies—and these injuries did not present serious diagnostic difficulties except in their variety and number. Injuries to the head, neck, and trunk, however, though less frequent, introduced numerous diagnostic problems (fig. 182).

Early in the war, for the purpose of discussing and comparing notes on radiologic problems, the Army, Navy, and civilian radiologists on Oahu and the surrounding area instituted monthly conferences which continued throughout the war. These meetings served a twofold purpose. They maintained morale and camaraderie within the specialty, and they furnished the opportunity for the presentation and discussion of interesting and unusual cases, particularly nontraumatic conditions.

Among the points discussed and the impressions gained at these meetings were the following:

1. Radiologic examination of combat-incurred wounds and fractures, important as it was, proved, for the most part, merely routine. The value of views in two projections was emphasized in all fractures, as was the importance of special views in fractures of the carpal navicular bone, the clavicle, the neck of the femur, and other areas. Also important, as Col. Leslie M. Garrett, MC, emphasized, was the periodic reexamination of casualties with fractures, chest wounds, and other injuries.

2. In view of the number and seriousness of the compound comminuted fractures encountered, there was remarkably little osteomyelitis. The use of penicillin, first employed in this area in January 1944, undoubtedly played a part in holding down the incidence of infection. Osteomyelitis attenuated

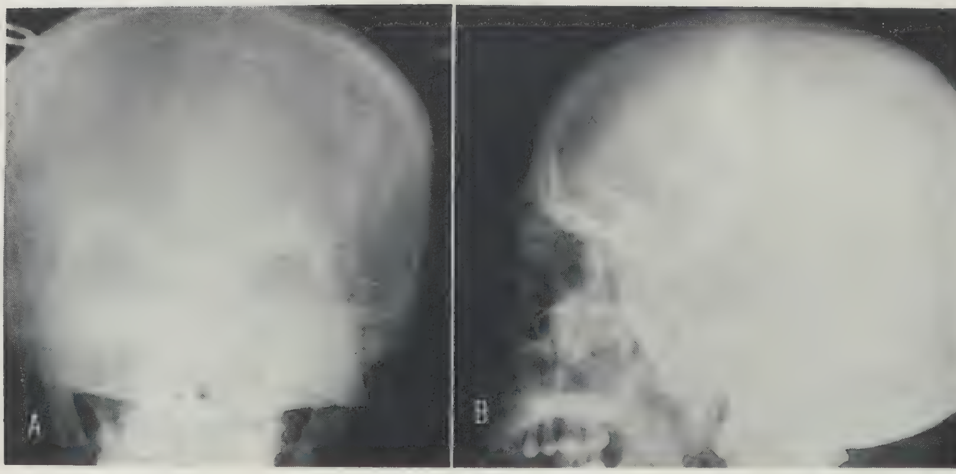

FIGURE 182.—Roentgenogram of skull, showing large shell fragment lodged in infratemporal fossa. Point of entrance was through nose and maxillary sinus. These radiographs illustrate the advantages and diagnostic adequacy of views in two projections for foreign body localization. A. Anteroposterior view. B. Lateral view.

by antibiotic therapy, Col. Robert C. Robertson, MC, reported, was sometimes observed.

3. The incidence of fractures of the carpal navicular bone was high, and aseptic necrosis of the proximal fragment was a frequent complication (fig. 183), particularly if the fracture was not recognized immediately or if initial immobilization was not adequate.

4. Separation of the acromioclavicular joint was frequently encountered, particularly in men participating in the strenuous training for jungle fighting.

5. The incidence of arthritis of the sacro-iliac joint was unexpectedly high (fig. 184). The involvment, which was usually bilateral, was characterized by a combination of subarticular sclerosis and irregular destruction of the articular surfaces. Symptoms often appeared after rigorous field training or after combat. Chronic prostatitis was a fairly frequent associated finding. The disease closely resembled that seen in association with rheumatoid spondylitis of the Marie-Strümpell type (fig. 185), except that there was usually little or no spinal involvement.

Osteochondritis dissecans was seen fairly frequently, most often in the distal femoral articular surface, but it was also observed in the hip, thoracic spine, ankle, carpal area, and the distal end of the second metatarsal bone.

7. Osgood-Schlatter disease (or at least the symptomatic residual ununited bony fragments characteristic of this condition) was ofter observed.

8. Several dozen cases of pulmonary coccidioidomycosis, with positive radiographic findings, were observed in soldiers arriving in the Hawaiian Islands from various training camps in California. The most frequent pulmonary lesion was a solitary area of infiltration or nodulation (fig. 186).

FIGURE 183.—Radiograph of wrist showing aseptic necrosis of carpal lunate bone with condensation and fragmentation.

Cavitation was observed in some of the nodular lesions. In some instances, infiltration or fibrosis was more widespread, and pleuritis was sometimes observed.

9. Twelve or more cases of lung fluke (paragonimiasis westermani), with positive radiographic findings, were seen among Korean prisoners of war interned on the island of Oahu. The lesions were usually small and confined to the upper lobes. They somewhat resembled tuberculosis, particularly when cavitation was associated. In other instances, the infiltration or fibrosis was more diffuse, and pleuritis might be associated (fig. 187).

10. At intervals throughout the war, successive waves of so-called primary atypical pneumonia were encountered in U.S. Army troops in the Central Pacific Area, 100 or more patients sometimes being on the wards of the larger hospitals at the same time. Radiographic findings usually consisted of single or multiple patches of infiltration or consolidation, most often involving the bases, though any portion of the lungs might be affected. The X-ray findings were frequently more extensive than the symptoms or the physical findings suggested, and it was not unusual for 2 to 4 weeks to elapse before they disappeared.

FIGURE 184.—Radiograph of lower spine and pelvis showing arthritis of sacro-iliac joints in 26-year-old soldier. Note the erosion and sclerosis of the joint margins, without roentgenologic changes in the spine or other joints. This man gave a history of intermittent low back pain since his induction into the Service 3½ years earlier, with severe recurrence of symptoms after heavy duty on Saipan.

Several radiologists on Oahu observed an interesting phenomenon in atypical pneumonia, the development of an area of cavitation or cyst formation within an area of pneumonia. In the early stages, such cavities had all the characteristics of a lung abscess, including a fluid level. The patient, however, had neither the foul sputum nor the septic temperature curve typical of putrid pulmonary abscess. As he was followed radiologically over a period of weeks, the surrounding pneumonia would resolve and the wall of the cavity became thinner, leaving only a cyst or bulla (fig. 188). Some of these thin-walled pseudocysts resolved completely, but others persisted during the period of observation.

In connection with these observations, it is interesting to recall that one of the first descriptions of this type of pneumonia was published by an Army radiologist, Maj. (later Col.) Albert Bowen, MC, who observed it among troops in Oahu in 1935 (*1*).

11. Very few radiographic lesions were observed in Army inductees from the Hawaiian Islands in their preinduction chest films. Among 4,700 Japanese, Korean, and Italian prisoners of war who had chest radiographs (photoroentgenograms), the incidence of tuberculosis was 1.5 percent. A higher rate had been anticipated, especially among the Orientals.

FIGURE 185.—Radiograph of spine showing typical changes of longstanding rheumatoid spondylitis (Marie Strümpell arthritis). Note obliteration of sacro-iliac joints and calcific bridging in intervertebral ligaments between various lumbar and low thoracic vertebral bodies.

12. An unusually high ratio of duodenal to gastric ulcers (fig. 189) was observed; at Tripler General Hospital, Honolulu, T.H., the ratio was about 30:1. The youth of the group perhaps explained the preponderance of duodenal ulcer.

13. Barium enema examinations produced a very low return of positive findings, to be explained again, perhaps, by the youth of the group examined. Subacute or latent amebiasis produced no detectable radiographic changes in the large bowel.

RADIATION THERAPY

Superficial X-ray therapy was used fairly extensively in fixed hospitals, especially if a qualified dermatologist was available to assist in the selection

FIGURE 186.—Posteroanterior roentgenogram of chest showing round, discrete nodules in both lungs. This patient's history and the clinical findings were compatible with coccidioidomycosis.

of cases and prescribe adjunct medication. Dermatophytosis of the feet and hands was the most usual condition treated; its incidence in this area was high. The response to 4 or 5 treatments of 50 to 100 r each was likely to be good, provided that the treatment was applied at the right stage and supplementary dermatologic therapy was also used. Superficial X-ray therapy was used for certain other selected skin infections, acne, external otitis, and plantar warts. A few cancers of the skin and lip were also treated with this modality.

Only two hospitals in the entire Central Pacific Area were equipped to perform intermediate and deep X-ray therapy. A 200-kv. machine was used at the 219th General Hospital at Schofield Barracks, and a 140-kv. machine at the 218th General Hospital (formerly Tripler General Hospital), on Oahu. Both machines were used for the treatment of acute or subacute peritendinitis, certain soft tissue abscesses, cellulitis, and adenitis. Only a small number of patients with malignant disease were treated; by regulations, such patients were evacuated to the mainland. If, however, evacuation was delayed or special circumstances existed, treatment was applied in certain selected conditions, such as malignant lymphoma, testicular malignancy (after surgery) and other radio-responsive neoplasms.

FIGURE 187.—Anteroposterior roentgenogram of chest showing patches of infiltration in right upper lobe and mid left lung field. The patient was a Korean prisoner of war. The clinical diagnosis of pulmonary paragonimiasis westermani was confirmed in the laboratory.

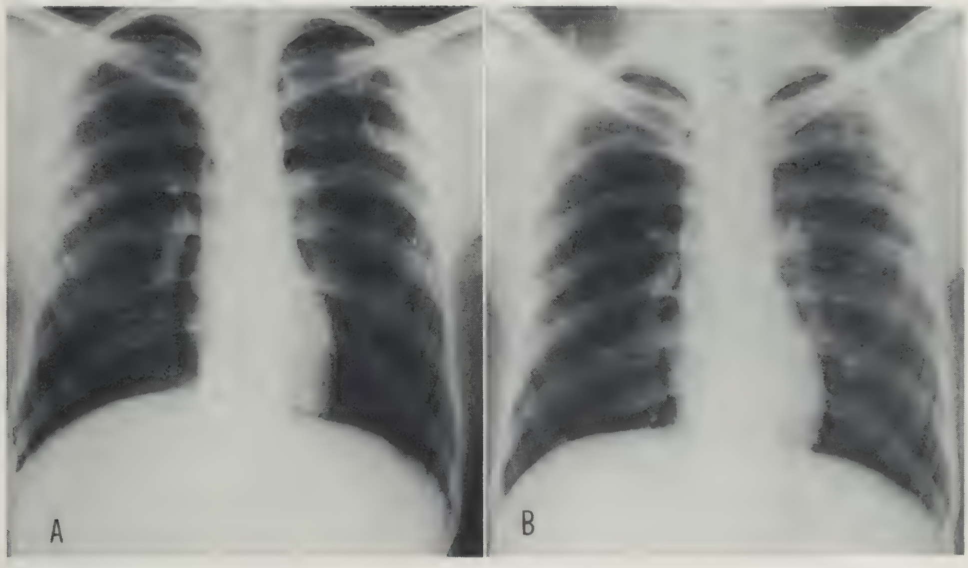

FIGURE 188.—Primary atypical pneumonia with residual cyst formation. The symptoms were minimal, and repeated sputum examinations were negative for acid-fast organisms. A. Posteroanterior roentgenogram of chest, 15 December 1944, after episode of primary atypical pneumonia. Note thin-walled cavity in left upper lobe. B. Same 21 January 1945. Note decrease in size of cavity (or cyst). The final diagnosis was resolving nonputrid abscess of lung or infected pneumatocele after primary atypical pneumonia.

FIGURE 189.—Roentgenogram of gastrointestinal tract after ingestion of barium showing typical duodenal ulcer with crater and deformity of cap.

Clostridial Myositis

X-ray therapy was used in the management of a number of cases of clostridial myositis (gas gangrene) among the casualties from Pearl Harbor. The first case was diagnosed on 8 December 1941, the day after the attack, and by that night eight others had been diagnosed. By the following day, 25 cases had been diagnosed, in all of which cultures were positive for *Clostridium welchii.* A number of other cases were suspected, and a close check was made on all radiographs for possible subcutaneous emphysema.

Clinically, the diagnosis was simple. The rotten, putrid appearance of the wounds and the nauseating stench frequently associated were characteristic. As soon as the diagnosis was suspected on X-ray evidence, the surgical section was notified, and the wounds were immediately opened, debrided, and dressed with sulfanilamide. Radiation therapy was then instituted. The patients were kept segregated.

A General Electric Maximar 200-kv. machine was kept busy for a number of hours each day in the treatment of these patients. All received an initial dose of 200 r and 100 r twice daily thereafter until a total dosage of 700 to 800 r had been applied to each part. The physical factors were 140

kv., ½ mm. cu., 1 mm. Al., 5 ma., at 50 cm. T.S.D. (Target-Skin Distance). These were anti-inflammatory doses.

Many of these patients were so close to death that it seemed hopeless to treat them, yet all recovered, and no amputations were necessary because of the infection. One patient, who had had a thigh amputation after injury, required so extensive a debridement that the femoral artery could be seen pulsating. Under the circumstances, it is remarkable that he and all the other patients with gas gangrene went on to good recoveries.[1]

REFERENCE

1. Bowen, A.: Acute Influenza Pneumonitis. Am. J. Roentgenol. 34:168–174, August 1935.

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[1] In ETOUSA (European Theater of Operations, U.S. Army), it became the duty of the Senior Consultant in Radiology to issue instructions that radiation therapy not be used in the management of clostridial myositis because only Picker portable units were available and there were no r-meters to measure the dose. It was feared, in the circumstances, that the patients would be undertreated and that surgeons, thinking they could depend on X-ray therapy, would be tempted to perform less extensive debridements than the condition demanded.—K. D. A. A.

South Pacific Area

and

Southwest Pacific Area

CHAPTER XXV

South Pacific Area[1]

Webster H. Brown, M.D.

HOSPITALS

Within the South Pacific Area were all varieties of hospitals from large affiliated general hospitals (fig. 190) through the gamut of evacuation, station, field, and portable surgical hospitals, or even combinations of field, evacuation, and station hospitals.

Many of these hospitals, especially the smaller units, moved repeatedly, as might be expected, since their mission was to care for troops that were constantly moving forward by the military plan of so-called island hopping. The constant shifting of personnel and equipment meant much time wasted—at least from the professional standpoint—in tearing down, moving, and setting up for renewed operations. Later in the war, even larger units underwent frequent changes of location. The hospitals sometimes moved as a whole, but quite often they were broken up and reassigned piecemeal, wherever the need for them was greatest. Every such move meant some loss of, or some damage to, X-ray equipment. Radiology in motion is difficult and is almost as damaging to equipment as motion is to films.

Workload.—The X-ray material was, naturally, overwhelmingly male, but otherwise was widely varied. It was not uncommon to have in a single hospital at the same time U.S. Army and Air Force patients, Navy patients (who were transferred as soon as practical to Navy installations), a few coastguardsmen, an occasional merchant seaman, some New Zealand troops, a sprinkling of civilians, and even a few natives.

The radiologic caseload was typical of the patient load in hospitals in the area. The curve began with a small number of patients examined with great difficulty in bed or on mess tables in makeshift quarters and rose gradually to a maximum of 50, 60, or even 90 patients per day during periods of intense activity. Then the work gradually tapered off to a low of 8 to 15 per day, or even less, the decrease generally being an indication that the unit

[1] The material in this chapter is chiefly prepared from the writer's own recollection of his experience in the South Pacific Area, supplemented by the rather limited number of replies he received to a questionnaire sent out in 1959 to other radiologists who served in this area. The official records of hospitals assigned to it contained very little information on radiology, this service apparently being one of the things taken for granted in their operations.

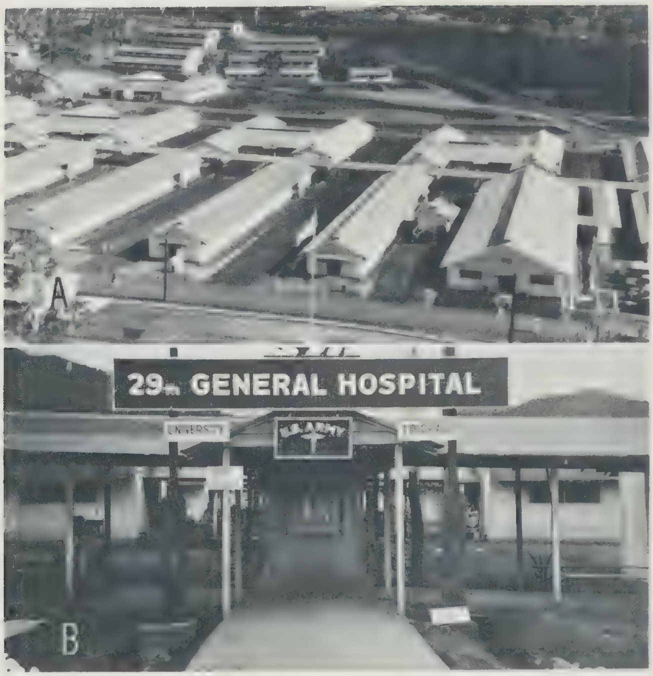

FIGURE 190.—29th General Hospital, New Caledonia, 1944. A. Portion of hospital which was of cantonment type with concrete floors. Operating rooms and X-ray section were in the extra-wide wing in the foreground. B. Entrance to the hospital.

would be moved, usually forward, to set up again or to merge with a unit already operating in the new assignment.

PROFESSIONAL PERSONNEL AND ASSIGNMENT

There were not enough qualified radiologists available to staff all the hospitals in the South Pacific Area, and often other medical officers, including an occasional general practitioner, were pressed into service in radiology departments. The original planning, of course, had been much too generous in relation to radiologic resources. The tables of organization for a 1,000-bed general hospital called for three radiologists (colonel, major, and captain), while that for a 500-bed hospital called for two (major and captain). These provisions were never met, nor as a rule was it necessary that they should be. Depending upon the workload and the type of work, a single trained radiologist could handle the work of a 500-bed hospital with relative ease, or even that of a 1,000-bed hospital when it was not extremely busy. If a second or a third radiologist had been provided in these installations, he would surely

have found himself the target for many nonradiologic assignments and duties if he had not been promptly reassigned to an inadequately staffed hospital.

Records concerning the radiologists who served in the South Pacific Area between 1942 and 1945 are somewhat confused. Eighteen (of whom eleven were Board-certified) are officially listed, but one of them on returning his questionnaire stated that while he had been originally assigned to the South Pacific Area he had really served all of his time in India. At least two other officers known to have served as radiologists in the South Pacific are not listed in the official files. One of them, certified in dermatology, replaced a radiologist who developed hepatitis at the port of embarkation. He himself developed a posterior gastric ulcer and had to be returned to the Zone of Interior. The other unlisted radiologist was chief of a service and supervised the work of a "conscripted" radiologist, formerly a general practitioner, who continued in this specialty after the war and was certified by the American Board of Radiology. This officer spent 2 months with Maj. (later Lt. Col.) Webster H. Brown, MC, at the 18th General Hospital and frequently, after he had been assigned elsewhere, drove 150 miles over bad roads to carry radiographs to him for consultation.

The shortage of radiologists is apparent if, accepting 19 (8 noncertified) as the number who served in the South Pacific, one considers the number of hospitals that they were obliged to serve:

Date of survey:	*Number of hospitals*
February–November 1942	14
January 1943	13
July 1943	21
April 1944	40
January 1945	24
July 1945	4
October 1945	4

The fluctuations in the number of hospitals just listed, like the fluctuations in the hospital population curve, reflect: the influx of troops, the building up of attacking forces, and then the recession (at first gradual and later rapid) of the fighting war as it moved out of this area and toward Japan and the end of combat in August 1945.

The shortage of radiologists was not too serious when several hospitals operated in the same area. Then there was a free exchange of facilities, supplies, personnel, service, and professional advice. The sharing of experiences not only resulted in the exchange of much useful professional and technical information but was also of great value in the elevation of morale.

The radiologists who were assigned to the South Pacific Area were used, practically without exception, for radiologic duties or spent the major portion of their time in such duties. Those who responded to the questionnaire sent out in 1959 to obtain material for this chapter all agreed on that point. In the single instance in which other duties were assigned to a radiologist,

the reason was to obtain for him the promotion that he might otherwise not have received after several years' service in the area.

LIAISON

Other U.S. radiologists.—Radiologists generally reported pleasant and profitable relations with other radiologists and other hospitals when they were close enough for contact with them. The rapport between Army and Navy installations varied. In some instances, there was no contact at all, even when the hospitals of the two services were quite close to each other. In other instances, liaison was strikingly good, and Army and Navy radiologists worked together and assisted each other professionally and technically. Although personal relations should not be the basis for contacts in a wartime effort, the existence or nonexistence of relations often seemed entirely personal.

Army hospitals had little contact with Army Air Force hospitals. There were only a few of the latter, and those that were encountered were even more frenetically in motion than comparable Army and Navy units, which, at least in comparison, tended to be relatively fixed. There were, however, many Air Force patients in Army hospitals in the South Pacific.

Allies.—There was excellent cooperation between U.S. hospitals in all services and the few New Zealand and Australian units that served in forward areas.

Native installations.—The location of the 18th General Hospital, near Suva, made it possible for its radiologist to serve frequently as consultant at the Colonial War Memorial Hospital there. This hospital, of 209 beds, provided the clinical teaching material for the medical school that trained NMP (native medical practitioners), who were well and favorably known throughout the islands. These practitioners did wonders without the refinements of modern medicine, including radiology. The course of study at the school lasted 4 years, and some of the graduates became highly astute in both diagnosis and therapy. A physician high in government medical circles, who died of cirrhosis in the 18th General Hospital during the war, told the following story: Some years before, while in an isolated spot in the islands only occasionally reached by boat, he fell ill with high fever and other symptoms that led an NMP to make a clinical diagnosis of amebic liver abscess. Since it would have been months before the patient could have reached Suva, the practitioner, with some advice from the physician-patient, drained the abscess. Recovery was complete, as evidenced by the official's subsequent years of active service.

In 1940, the school enrollment included 18 Fijians; 2 East Indians; 9 Western Samoans; 1 Eastern Samoan; 4 Tongans; 5 Gilbert and Ellice Islanders; 4 Solomon Islanders; 2 New Hebrideans; 1 Rotuman; 2 Nauruans; 2 Cook Islanders; and 1 Niuan. All were in their third or fourth years.

The contacts with faculty and students were mutually helpful. In appreciation of the assistance given the school by the staff of the 18th

General Hospital, all members of the staff were issued licenses to practice medicine in Fiji. The experience in such a region might possibly be rewarding.

Major Brown and two technicians from the 18th General Hospital were flown to Makogai, the site of the world-renowned leper colony, in an American built PBY ("Catalina") flying boat, piloted by an officer of the New Zealand Air Force. This colony receives lepers from the entire adjacent region, including Tonga, Fiji (only 80 of whose 250 islands are inhabited), the Solomons, the Gilberts, and the Ellice Islands. Major Brown's mission was to finish setting up and checking the first X-ray equipment ever available in the community. Most of the population of nearly a thousand persons were sick, and many of them were maimed and deformed. The first 8 or 10 patients examined were also X-rayed, and the technicians set up a simple technique for use with the equipment installed, which was relatively rudimentary. The help thus rendered was only one of numerous other efforts by U.S. radiologic personnel to be of service to the natives.

X-RAY TECHNICIANS

The work of the X-ray sections of hospitals in the South Pacific could not have been done without the devotion and ability of the enlisted technicians, many of whom had been trained in short courses in the Zone of Interior (p. 40). When civilian-trained registered technicians were available, as they occasionally were, they were able to compound the efficiency of the Army-trained technicians, many of whom, however, learned very rapidly and became very valuable workers. At the outset, the chief radiologic knowledge of these rapidly trained technicians seemed limited to assembling, disassembling, and packing of the Picker field unit and the taking of radiographs with it. There was great rivalry among small teams working together, who measured their relative efficiency by the number of minutes required to accomplish assembly or disassembly of the field unit. At one particular time, this ability seemed a valuable asset: Soon after a hospital arrived at a presumably permanent location, it received two sets of directly contradictory orders. One set was to prepare to receive casualties at once, and the bed capacity of the hospital, along with its X-ray facilities, was increased by tentage by a factor of 5 within 48 hours. The other set of orders gave instructions to preserve all packing cases and material and be ready to move at a moment's notice. The first set of orders proved correct, and the hospital was prepared for the casualties when they arrived.

X-ray technicians were very ingenious men, and their ingenuity, based on observation and experience, helped to overcome shortages and lack of adequate equipment. They often seemed, in fact, to take delight in surmounting obstacles unknown in civilian life. One of the major difficulties was caused by the climate. Films produced by portable equipment had to be developed in a canvas tent suspended from the rafters of a prefabricated

hut, with the temperature outside 90° F. or more, the humidity in the same high range, and the temperature in the darkroom tent more than 120° F. Standard procedure was to develop the film, rinse it lightly, immerse it in hypo, and then shout to those outside the tent to raise the sides immediately. Under these circumstances, the technicians emerged looking like engineers in a boilerroom.

One source of technicians was patients who had been detached from active combat duty and attached to noncombat units, including hospital units. The reasons for their detachment varied, but high among them were illness and psychiatric causes (so-called overtaxed and underequipped personalities). In the early part of the war, many combat units were National Guard units, which contained troops with a protean mixture of specialties and abilities, as well as many without special training and without ability of any kind. Many of these men were frankly unfit for combat responsibilities, but a number of them, although unsuited for their original assignments, developed into very useful technicians.

FACILITIES

Hospitals occupied prefabricated huts or were housed in tents or in available buildings, about which native huts were sometimes clustered. The general plan was to make the few connecting roads between the tents or buildings carry as much traffic as possible. After the facilities had been erected, they were surrounded by raw earth or, in many places, soapstone, which is unbelievably slippery when it is wet. The plentiful rain in the Tropics and the fecundity of the climate soon produced much vegetation around all new installations.

The best of radiologic installations was no more than a modest makeshift. By the end of its stay on Fiji, one whole end of the radiographic and fluoroscopic room of the 18th General Hospital was enclosed by large curtains, which could be thrown open after each use. Thorough airing was essential, not only because of the high temperature and humidity but because, even early in the morning, the blazing tropical sun generated smells of ham and cabbage from the roof of what had long been the kitchen of the boys' school in which this hospital was housed. The smell originating from a tarred roof and new wood, usually unpainted, is vivid in the memory of all who practiced radiology in temporary quarters in the South Pacific.

EQUIPMENT

Basic Equipment

All radiologists who replied to the questionnaire sent out to secure material for this chapter had very high praise for the Picker field X-ray unit. Because of unusually close tolerances, however, or perhaps because of

failure of insulation caused by moisture, mold, or both, nearly every control on the panel in some units was likely to provide an unpleasant shock when it was touched. All metal switches were therefore completely covered with rubber tubing, even when the entire unit was carefully grounded with a stake driven into the ground outside each tent or building.

When the portable unit was wheeled to the bedside, the stake was thrown, like a harpoon, into the ground outside. This was the preferred method; the attempt to drive a stake into the ground with a sledge hammer often meant total immersion by a precipitate tropical downpour.

Since there were no paved walks over which the portable units could be transported, they were stationed strategically throughout the makeshift wards, and the patients—not without an element of semantic irony—were brought to them on stretchers or by hand-carry. The experience suggests that it might be well to make the standard casters on portable X-ray units replaceable, the replacement to be a wheel of larger diameter, with a greater bearing surface area, so that a portable unit might be truly portable, even over uneven earth or gravel walks. The same plan might also be used on rolling litters, transportation on which often required as much lifting as pushing.

The major problems connected with equipment arose not from the equipment but from the climate. Rust and corrosion were frequent and occurred rapidly. Condensation on the equipment was enormous and far more than it had been expected that it would have to tolerate. The type of insulation designed for civilian practice in the United States could not long endure under the conditions in the Tropics, and climatic conditions were responsible for many breakdowns.

There was need for greater amounts of sheet lead and blackout material than had been provided, and also need for fire extinguishers.

Current

Another problem persistently encountered in the South Pacific Area had to do with an adequate and efficient supply of current. Local current was seldom available in sufficient amounts or in correct voltage. Units in various situations operated on widely variable types of generators. The field unit could be used fairly efficiently with the small emergency generator supplied with it, but larger units required larger generators, which often were located at a considerable distance from the X-ray section, while wiring heavy enough to be used for connections was frequently not available.

Even these difficulties could be surmounted, at least to some extent, by utilizing the equipment with the current available on a basis of trial and error. Sometimes it was possible to induce the commanding officer of the hospital to set aside a certain portion of the day during which current would be reserved for the X-ray department and used for other purposes only in emergencies. It was also found that even typical British 50-cycle current

could be utilized if the U.S. tube safety rating was reduced to five-sixths of the stated rating.

One thing was certain: Both radiologists and technicians appreciated the scarcity of equipment and the practical impossibility of replacing units or their parts. As a result, the safety factor allowance for error was probably greater than had ever been made before in the history of radiology. Numerous expedients were adopted to minimize the use of equipment, to avoid strain beyond the 50-percent point as it was realized, and to eliminate unnecessary examinations. As a result, to avoid even a remote chance that reexamination would be necessary, preparation of the patients for special examinations was generally remarkably good.

Accessory Items

Before adequate equipment was available and in operation, it was found possible to examine even fairly heavy parts of the body with the patient in bed if the grid was taken out of the standard Army portable table unit. Because of the humidity, grids rapidly twisted out of shape, and both fluoroscopic and radiographic screens curled at the edges and soon became damaged or entirely unusable. A film drying unit would have been of little use without a heating or moisture-absorbing device. Large and numerous exhaust fans would have been useful. A more basic approach to the problem, however, would seem advisable. In other words, moisture- and humidity-proof grids, screens, and other items should be considered mandatory for tropical installations.

It was soon learned that if radiographic screens were to last any time, all cassettes must be unloaded every night and reloaded in the morning. Otherwise the emulsion would stick to the screens, and the resulting defects would produce artifacts. Whenever there was a dry day, all cassettes not in use were unloaded and allowed to dry outside, away from direct sunlight.

The localizer provided for foreign bodies in the eye did not prove useful in this area, and most radiologists, like those in the European theater (p. 466) and elsewhere, preferred the smaller, simpler Sweet apparatus. Several radiologists had substitutes for the Sweet apparatus made by engineers near them, and others secured the apparatus personally from the United States.

Improvisations

Radiologists and technicians, whether qualified or impressed into radiologic service, if they lacked native ingenuity soon found it necessary to become ingenious. Some found, for instance, when it was impossible to secure a fluoroscopic room sufficiently dark for daytime work, that examinations could be made very satisfactorily at night, on the beach, though the brilliant tropical moon was sometimes a definite disadvantage.

It was found that satisfactory chest examinations could be made if the

tube was fixed at a safe, properly centered position with a fixed wooden cassette holder on the wall. This was accomplished by positioning the patient on a truncated triangle.

Men 5 feet 4 inches stood with their feet on the flat central portion of the platform, while those 6 feet and over stood with their feet outside the device and spread apart as necessary. Those in between these heights were positioned on the inclined ramp. This technique prevented damage to the tube, which could be locked firmly and safely only with the tube stand at an angle of 45° to the tabletop.

An adequate erect sinus device was made with a few nails and some crating material. Several pieces of stiff wire joined at the upper and lower ends, with reversed hooks to fit over the fluoroscopic screen, permitted spot films to be made in the erect position.

Maintenance

Communications among the farflung U.S. medical installations in the South Pacific Area were quite good, but supply was often slow and unreliable and service was very strictly limited. One might almost say that the type of medical practice here reverted to that of the frontier days in the United States when medical attention, such as it was, was limited to armed outposts or forts. In those days, the outposts received supplies infrequently and often in inadequate amounts, so that each was forced to function almost as an independent operating unit and to do the best it could with what it had. This situation generally prevailed in hospital units in the South Pacific, and it put a specialty such as radiology, depending, as it does, upon fairly complex equipment, at a distinct disadvantage.

How inadequate maintenance of X-ray equipment was is best pointed up by the reply to one of the questionnaires sent out in 1959 to all radiologists who had served in the area. One of the respondents simply put a question mark after the query about the service rendered to radiologic equipment, on the ground that up to that time he had not realized that there had been any service at all in the South Pacific. It had seemed perfectly natural to him to make his own repairs, with the aid of an unusually efficient technician and such nonradiologic help as he could secure.

FILMS

Processing.—Solutions made with water from the ordinary Army purifier-chlorinator system deteriorated rapidly, and ordinary filtered water with a fungus deterrent added was preferable. Distilled water was used when it was available, and rainwater was sometimes used as a last resort. A fungus deterrent placed in wash tanks overnight partly reduced film spoilage as well as the necessity for frequent cleaning of the tanks.

Since, as just indicated, the water supply was far from ideal and often

contained foreign material, it was found best to use an adequate, readily cleaned strainer on the intake of any developing or washing unit. The presence of air in the line impaired the function of the circulator and refrigerator unit, and it was suggested that, in addition to the strainer employed, and possibly in conjunction with it, there should be an adequate air bleeder system, especially when the operation was interrupted. Field plumbing, like many other field services, was usually of the quick, make-do variety and was not governed by city building codes.

Handling.—Space for storage and filing of radiographs was at a premium in X-ray sections, and an acute need was felt for some means of miniature reproduction, which would have permitted their ready transportation for central storage in the Zone of Interior. Radiographs often accompanied the patients on their transfer to other installations, either in the South Pacific or to the Zone of Interior (p. 340), but the system was not employed routinely, and in some instances the films were lost or mutilated.

CLINICAL CONSIDERATIONS

The clinical material that passed through the X-ray departments in the South Pacific Area was seldom anything but routine. Only occasionally were interesting or really unusual conditions encountered.

There were, however, a number of instances in which the diagnosis was not clear and the patient was transferred before it could be made. One curious radiologist secured a supply of penny postcards and included them, self-addressed, in the records of these patients. His results were not too good, and it is unfortunate that some official system did not exist to follow up patients; the use of serial numbers would have made such a procedure simple.

Radiologists in the South Pacific often maintained their interest in certain of these patients and tried to follow them up personally. Years later, one of them was able to trace the family of one patient he had seen and thus learned his present status, which was excellent: This man had had a large mediastinal mass, which, when it was removed, proved to be a branchiogenic cyst, attached to the esophagus and not related to the respiratory system. If information of this kind could have been relayed to radiologists who had seen these patients in the field, it would have been a decided aid to morale, particularly if they had been fortunate enough to make correct diagnoses.

As a result of wartime secrecy, mail was held up for months, and medical journals were correspondingly late in arrival. This was unfortunate. Much current clinical information could have been secured by regular reading of the periodical literature. Journal clubs could also have been formed with profit.

Because of the scarcity of interesting clinical material, as well as the lack of adequate reference material, almost no clinical experiences were recorded for publication in the South Pacific. The improvisations mentioned,

ingenious as many of them were, were not likely to be useful in a modern, well-equipped X-ray department and also went unrecorded.

Radiologic examination was sometimes useful in preventing soldiers from carrying out the purpose of what was known as "riding their gallbladders home." The dye used for gallbladder examinations was administered in capsules that also contained barium sulfate. If no barium was found in the gastrointestinal tract the day after the dye had presumably been ingested, the suspicion seemed warranted that it was not a nonfunctioning gallbladder but failure to ingest the capsule that explained the negative results.

THE CONSULTANT SYSTEM

It is extremely unfortunate that there was no consultant system in radiology in the South Pacific Area as there was in medicine and surgery. If anything, there was more need of such a service in radiology, a specialty which depends upon the operation of complex equipment, which was often provided by medical officers with little or no training in it, and which impinges upon all other fields of medicine.

The consultant system, as other theaters proved, is also an excellent means for dissemination of information. Such channels were practically nonexistent in the South Pacific, where some radiologists reported that they had scarcely ever moved beyond the locations in which their units were first situated.

In any future radiologic area such as the South Pacific, an organization should be set up consisting of a consultant who is an experienced radiologist and a small group of trained assistants who could be dispatched for consultation and advice to any area in which they might be needed. Such a system would raise the level of radiologic practice and would be of great comfort and assistance to radiologists in the area, particularly those with meager training, as well as to medical officers assigned to radiology without any training at all in that specialty.

CHAPTER XXVI

Buildup of Medical Facilities[1]

Charles W. Reavis, M.D.

THE PHILIPPINES, 1941–42

The Medicomilitary Situation

The duration of Army medical service in the Philippines after the United States was precipitated into World War II was brief and dramatic. When the Japanese bombed Clark Field, Luzon, immediately after their attack on Pearl Harbor, the department surgeon, Col. Wibb E. Cooper, MC, and his staff had to convert rapidly from the routine activities of an Army oversea department to those of an active theater of operations. The story was one of medical service rendered under extreme difficulties. The withdrawal to Bataan and Corregidor was, it is true, in accordance with long-established military plans, but the administration of medical service during the retreat followed no formal pattern and was adapted, of necessity, to the exigencies of the rapidly changing military circumstances.

In December 1941, the total fixed Army medical assets in the Philippines were represented by Sternberg General Hospital in Manila and five station hospitals in other locations. The wounded could be cared for in them only until the move to Bataan began, in late December 1941. When the Fort Mills Station Hospital sustained several direct hits in the first bombing of Corregidor, also in late December, its facilities were immediately moved to Malinta Tunnel. Early in April, after the evacuation from Bataan to Corregidor took place, all medical service in the Philippines was concentrated in this tunnel, with Colonel Cooper in charge. The patients included not

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[1] The account of radiology in the Southwest Pacific Area in World War II that appears in this and the following chapters was made possible by the generous cooperation of many of the radiologists who served there. When the preparation of this volume was undertaken, 12 years after the end of the war, they were asked to relate their experiences, and their cordial response was as encouraging as their information was valuable. Much of it did not exist in any official record.

Because in many—indeed most—respects their experiences were overlapping, it was impossible to publish their individual accounts. Full credit, however, for the following material is due to: Vernon L. Bolton, M.D.; William C. Coles, M.D.; Donald B. Fletcher, M.D.; Horace D. Gray, M.D.; Ralph L. Moore, M.D.; Joseph L. Morton, M.D.; Ernest B. Newman, M.D.; Sidney Rubenfeld, M.D.; Walter J. Stork, M.D.; Frederick W. Van Buskirk, M.D.; Harold A. Vinson, M.D.; and Egon G. Wissing, M.D.

only combat casualties but many others suffering from malaria, malnutrition, and dysentery.

Colonel Cooper and his staff remained in the tunnel with their charges until after the surrender of Corregidor, on 6 May 1942. Late in June, the Japanese permitted them to move from it to the renovated Fort Mills Station Hospital. In early July, patients and medical officers were sent to Bilibid Prison and the nurses to Santo Tomas University, Manila, which had been converted into a prison. At this time, all semblance of medical organization in the U.S. Army in the Philippines may be said to have ended.

Radiology

Shortly before the United States entered World War II, Lt. Col. Theodore Winship, MC, was placed in charge of the station hospital at Fort William McKinley. He had had no training in radiology, but in the absence of a radiologist, he necessarily assumed those duties also.

Two days after the attack on Clark Field, Colonel Winship was made chief surgeon of the 500-bed hospital at the Philippine Women's University. There his radiologic activities were limited to attempts to obtain radiographs on patients who needed them most.

On 25 December 1941, this hospital was dismantled and sent to Camp Limay, to become part of General Hospital No. 1, which had been set up there after the move to Bataan. At the end of January 1942, General Hospital No. 1 was moved to Little Baguio. It sustained several direct hits in a bombing attack late in March 1942, and when it was bombed again, on 7 April, its functions were completely disrupted.

The radiologist at General Hospital No. 1 was Maj. (later Lt. Col.) Edward J. Kallus, MC, who had once served as radiologist at Sternberg General Hospital. His section was located in one of the few wards that had a cement floor and a corrugated iron roof. The equipment was an old machine, of the 60- to 80-kv., 15- to 20-ma. type. Patients were carried into the X-ray room, and films were developed across the road, in a darkroom that consisted of a blacked-out area, about 6 by 8 feet, below the surgicial building.

AUSTRALIA AND NEW GUINEA

Even before the surrender of Bataan, and later of Corregidor, medical service in SWPA (Southwest Pacific Area) was beginning to take shape in Australia. It began with the appointment, early in 1942, of Col. (later Brig. Gen.) Percy J. Carroll, MC, as ranking medical officer in the area, to take charge of Medical Department activities in USAFIA (U.S. Army Forces in Australia). Colonel Carroll had been on duty in the Philippines when the attack on Pearl Harbor occurred and had been able to collect a group of patients just before the fall of Manila and evacuate them on the small U.S.A.H.S. *Mactan* to Australia.

On 28 February 1942, the 4th General Hospital, with a number of casual medical officers in its personnel, arrived in Australia and set up at Melbourne. Two evacuation hospitals and several small station hospitals landed in April and were followed, in early June, by a number of other station hospitals and three affiliated general hospitals. For more than a year thereafter only a few station hospitals and a few casual medical officers were sent to SWPA.

Radiology

Each of the affiliated hospitals that arrived in Australia had at least one radiologist on the staff, and usually had two or three. These hospitals, as always, demonstrated one of the great advantages of affiliated units: Because their personnel had worked together, they functioned better sooner than heterogeneous officers who had been hastily formed into medical units. The quality of care was always high in affiliated hospitals in all sections, and its excellence raised the quality of medical care throughout the area.

The station hospitals that arrived in Australia in 1942 had on their staffs a number of medical officers who had had good training in radiology as well as a number of others who had had some limited training. Fully qualified radiologists, however, were always in short supply in SWPA throughout the war. As late as 26 April 1944, there were only 11 medical officers in the area who were diplomates of the American Board of Radiology. Of necessity, these were assigned to general hospitals, where they provided the foundation for radiology throughout the area.

Some medical supplies, including radiologic supplies, were immediately available in Brisbane from a U.S. convoy that arrived in December 1941, and a medical supply depot was at once set up there. For some time, however, most supplies were furnished by Australia. When supplies began to arrive from the Zone of Interior, and throughout 1943, Brisbane received the bulk of these supplies and was the chief distribution point for all parts of SWPA. Facilities and communications were far superior in the large ports of Brisbane and Melbourne in the southeast, where the Australian population was heavily concentrated, to those in the north around Darwin, where both roads and railroads were poor.

In the early months of 1942 and throughout much of the year, all the circumstances conspired to make the duties of medical officers assigned to the Australian Base Section unorthodox. These officers had to become acquainted with the personnel of Commonwealth and State medical agencies, with personnel of the Australian medical organizations, and with local sources of medical facilities and supplies. Medical personnel had to develop talent for diplomacy, for borrowing, for improvisation when facilities and supplies were not available, and for doing without when there was nothing else to do. All of these skills were not fully covered, if indeed they were mentioned, in Army field manuals or training courses.

The first station, evacuation, and field hospitals that arrived in Australia were placed in staging areas along the eastern shore. Here they handled the medical load for the troops that arrived in larger and larger numbers from the Zone of Interior. The patients, and therefore the radiologic load, were of the sort usually encountered in civilian life. At Brisbane, for instance, the first work included the supervision of an industrial health program for all Australians employed by the U.S. Army in the section (Base Section No. 3). By the end of 1943, this program covered about 10,000 employees, and the hospital and dispensary work, including the radiologic work, resembled that of service commands in the Zone of Interior.

Battle casualties did not begin to be received in Australia until the Buna-Gona campaign in November 1942, when U.S. and Australian troops started over the Owen Stanley Range in New Guinea, to drive the Japanese back from around Port Moresby. The base at Finschhafen, with the 26th Hospital Center providing most of the medical service, supported the major part of the preliminary 1944 offensive in New Guinea, while the base at Hollandia, with the 28th Hospital Center on Biak supplying most of the medical service, supported the invasion of Leyte in October 1944.

THE PHILIPPINES, 1944–45

The development of medical base facilities in the Philippines in 1944 and 1945 was slower than the buildup in New Guinea had been and was beset with many practical difficulties. Their establishment was extremely important because they were being built up to support the invasion of Japan, as well as on the assumption that after the Japanese surrender there would be a great increase in hospital needs. Actually, Japan did not have to be invaded, and the expected need for beds after the surrender did not materialize. By V–J Day, however, there was a considerable number of medical installations in the Philippines. Some had arrived from New Guinea, and a large number of general, station, and field hospitals had been sent directly to the Philippines from the Mediterranean and European theaters after the German surrender in May 1945. A few hospitals were moved into Japan after the surrender to care for occupation troops, but deactivation of most units began promptly in September 1945.

Much of the ground on which the initial U.S. landings were made in the Philippines was extremely swampy, and most hospital sites were in swamps or rice paddies. The Medical Department had no effective spokesman on the General Staff, and it therefore had a low priority for both hospital sites and unloading of supplies. Engineers were seldom available, and medical corpsmen, under direction of medical officers, did a large part of the construction work.

Hospitals were usually in tents and prefabricated buildings, the buildings being used for essential facilities and for wards for the more seriously ill

patients. Wooden floors for tents were constructed of dunnage. Rainfall in November 1944 totaled 21 inches, and in December 12 inches, and the downfalls greatly hindered construction work. Although numerous casualties required definitive care, no general hospitals were ready for service on Leyte until 26 November 1944, when the 133d General Hospital became operational. By the end of the year, three other general hospitals were also in operation.

The return to the Philippines presented the medical service with a number of special problems involving not only their own released prisoners of war but also the health of a large and friendly native population. A good deal of hospitalization had to be provided for civilian sick, for Philippine Army personnel, for U.S. residents of the Philippines, for civilians accidentally injured by U.S. Army personnel, and for troops without attached medical support. Many of the Allied prisoners of war had suffered greatly during their captivity and were in very poor health, so that every possible means, including the utilization of existing Japanese installations, was employed to expedite their care.

ADMINISTRATIVE PROBLEMS

There were numerous administrative difficulties in SWPA. In both the Central Pacific and the South Pacific Areas, a single surgeon was in authority, with a fairly complete staff under his control and with clear responsibility for area-wide medical service. In SWPA, there was no area headquarters for some months. During a later period, there was no surgeon at area headquarters. The Services of Supply headquarters, which operated the medical supply depots as well as the fixed hospitals that furnished most of the sustained medical care, was larger than the theater headquarters and was located at some distance from it. The number of Medical Department personnel with sufficient administrative background and training to staff both headquarters was not large enough for both, even if provision had been made for enough spaces, which had not been done.

In SWPA, therefore, there was some confusion concerning the respective responsibilities of the two medical headquarters, and during most of its existence SWPA did not have a full staff of consultants. As pointed out elsewhere, it had an acting consultant in radiology for some months (p. 565) but it never had a full-time consultant in this specialty.

Hospitals in SWPA functioned according to the needs of the time and place of their location rather than according to their official designation and mission. In all theaters there was a certain amount of flexibility in respect to hospital missions, but it was nowhere so frequent and so extensive as in SWPA, where a station hospital might find itself functioning as a general hospital, a general hospital as an evacuation hospital, and an evacuation hospital as a station hospital.

RADIOLOGY

While not a great deal has been said specifically about radiology in the preceding pages, actually, the provision of that special service is implicit in everything that has been said about hospitals, hospitalization, and the care of casualties. Radiologic personnel and equipment were integral parts of the general hospitalization plans; they were provided for in the tables of organization and equipment. There were, however, no special plans for the utilization of radiologic personnel in SWPA, or for the maintenance and supply of radiologic equipment.

Radiology is a highly complicated and highly technical specialty. It cuts across all branches of medicine and at the same time is integrated with them. Even more in wartime than in peacetime, the individual radiologist is called upon to satisfy the needs and desires of many other specialists, all of whom, like himself, are working under the pressures of an unprecedented patient load and with generally inadequate facilities.

Radiology in the Mediterranean and European theaters, like the entire operation of the medical services there, was centrally located and controlled. In SWPA, the situation was different. In the opinion of the radiologists who worked in this area, disorganization and confusion reigned from the beginning of the war to the end. Except for the several months in which Maj. Charles W. Reavis, MC, served as acting consultant in radiology, there were no radiologists to visit hospitals or to turn to for advice. There was no higher radiologic echelon to which to appeal; as a matter of fact, radiology was not represented at higher echelons. As a result, few directives were issued for the guidance of the inexperienced radiologist, whose need was particularly great because he was so often isolated for long periods with no contact with other radiologists. For these reasons, and because channels of communication were so poor, he was frequently called upon to make his own decisions. That the work was so well done is proof of the outstanding ability of the medical officers who provided both adequate and commendable radiologic service for the troops in SWPA.

CHAPTER XXVII

The Consultant System

Charles W. Reavis, M.D.

GENERAL CONSIDERATIONS

World War II ended before any officially authorized consultant system in radiology began to operate in the SWPA (Southwest Pacific Area). Full-time consultants in medicine, surgery, and neuropsychiatry were appointed during the war, and a consultant in orthopedic surgery served for part of the war. There was no full-time consultant in radiology at any time, and an acting consultant, appointed in September 1943, served for only a year before he returned to the mainland.

The confused headquarters situation in the SWPA, to which attention has been called elsewhere (p. 495), also made for difficulties in respect to consultants. At one time, they were used only in SOS (Services of Supply) headquarters. The first Surgeon, SWPA, held the view that consultants belonged in the Office of the Surgeon, and he was always unwilling for them to go into the field, where their services were greatly needed and where they would have been far more useful. For a considerable time, the authority of such consultants as were appointed was in question, and it was not always clear to whom they were responsible.

When Col. Maurice C. Pincoffs, MC, formerly professor of medicine at the University of Maryland School of Medicine, was appointed chief of Professional Services, Headquarters, U.S. Army Forces in the Far East, SWPA, in February 1943, considerable improvement resulted. Still further improvement resulted when Brig. Gen. Guy B. Denit, in January 1944, was appointed both Surgeon, SWPA, and Surgeon, SOS, SWPA. Both Colonel Pincoffs and General Denit had the correct concept of the contributions consultants could make to the care of the sick and wounded.

THE ACTING CONSULTANT IN RADIOLOGY

In September 1943, Maj. Charles W. Reavis, MC (fig. 191), was appointed Acting Consultant in Radiology to the Surgeon, SOS, SWPA. Major Reavis had come into the Southwest Pacific as chief of the radiologic service at the 42d General Hospital, which, at the time of this appointment, was located in Brisbane. He continued to serve as chief of radiology there

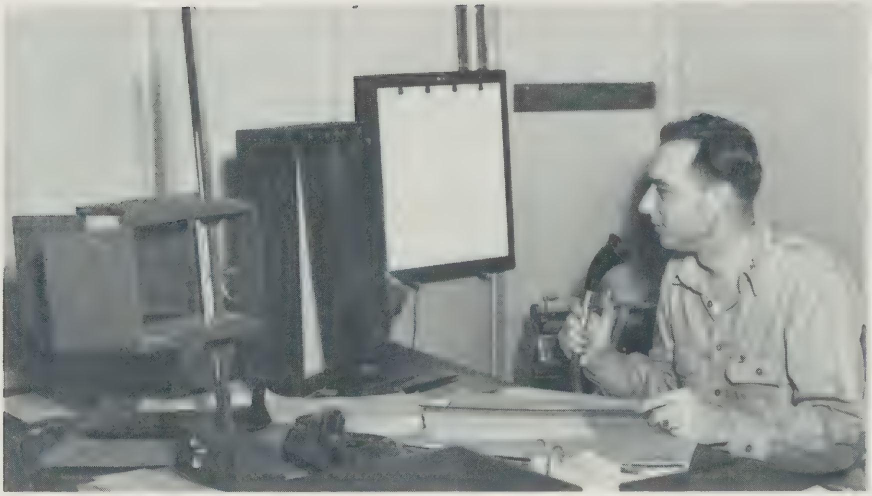

FIGURE 191.—Maj. Charles W. Reavis, MC, Chief of Radiology, 42d General Hospital, and Acting Consultant in Radiology, SWPA. Note improvised stereoscope on desk and old-type horn dictaphone still in use at this hospital in 1943.

during his entire tour of duty as Acting Consultant in Radiology; during his absences, his hospital duties were assumed by the other radiologists assigned to the department.

Major Reavis' appointment as Acting Consultant in Radiology continued more than a year, until November 1944. During September and early October 1943, he spent practically his entire time on his consultant duties, as he did from November 1943 to May 1944. Then, until his return to the States in November 1944, he spent from 50 to 60 percent of his time on these duties.

When Major Reavis returned to the mainland, he was not replaced, and no other consultant in radiology was appointed during the remainder of the war. This was unfortunate. A great many difficulties would have been avoided, and the radiologic service in this area could have been much more effective, with a full-time consultant. As already mentioned, the work of all consultants in the SWPA was complicated by failure to provide for them in tables of organization and by the peculiarly confused lines of command in this area.

Major Reavis' most important duties were in the field. His authorization for them was the letters he was given from General Denit to Col. Bascom L. Wilson, MC, Surgeon, Fifth Air Force, and to Col. (later Brig. Gen.) William A. Hagins, MC, Surgeon, Sixth U.S. Army. In these letters, both surgeons were offered such radiologic consultation and advice as Major Reavis could supply, and it was only because the offers were accepted by them that he received permission to inspect the radiology departments of the various installations under their command and to advise the departmental personnel.

He visited all SOS installations and also those of the Eighth Air Force and Sixth U.S. Army, but his activity was limited to advice. He had no real authority. On his return to headquarters, he made recommendations to the area surgeon through the chief of the Professional Services Division.

Major Reavis' own impression was that his major accomplishments in his tours of the area installations were achieved by personal contact. He was distinctly surprised, in studying the final reports used in the preparation of this chapter, to find that a very considerable number of his recommendations had been put into effect either by local action or by instructions from headquarters. It is typical of the confusion of so many of the activities in the SWPA that this information was so long delayed. The explanation is multiple: the number of headquarters involved; the number of persons concerned, with their multiple and often overlapping and conflicting missions; and, perhaps most important of all, the great distances and the poor communications in the SWPA.

In view of the vast distances in the Pacific and the quality of such communications as existed, radiologists, like other medical officers, were frequently on their own responsibility. Each of them had to perform according to his capabilities in the special situation in which he found himself. There were few regulations for his guidance. In fact, such directives as were received were frequently ignored because they were entirely impractical in the circumstances of tropical warfare, particularly on isolated islands. All of these considerations made it unfortunate that a full-time radiologic consultant, or at least the base consultants proposed by the Acting Consultant in Radiology (p. 570), were never appointed.

TOURS OF INSPECTION

Policies and Procedures

While he was Acting Consultant in Radiology, Major Reavis, at one time or another, visited almost every Army and Air Force installation in the Southwest Pacific in which there was any X-ray equipment. In early 1944, the number of these installations, including dispensaries as well as hospitals, was close to 70. On one typical trip he visited 2 general hospitals, 30 station hospitals, 1 air depot, 2 field hospitals, 4 portable hospitals, 3 evacuation hospitals, and 1 station hospital dispensary.

For various reasons, it was not practical for Major Reavis to inspect personally a small number of units that were staging or moving when it would have been convenient to visit them. Information concerning these installations was secured from Lt. Col. (later Col.) Garfield G. Duncan, MC, Consultant in Medicine, Sixth U.S. Army.

The general plan of all of these trips was the same. After the initial formalities had been concluded, most of Major Reavis' time was spent with the radiologist and his associates; or with those responsible for radiology if

a radiologist was not assigned to the hospital; and with the technicians. All of these personnel were given every possible assistance including advice concerning the correction of mechanical and other faults and deficiencies.

After his inspection of each installation, Major Reavis wrote a detailed report covering X-ray facilities; equipment in possession of the hospital, with a comment on whether it was all needed or whether more was needed; professional personnel, with comments on their training and performance; technical personnel, with similar comments; protection of personnel against radiation; the workload; files and records; library facilities; and staff conferences. Each report concluded with a comment on the capacity of the installation, the quality of work done in it, and such recommendations as were indicated concerning equipment, personnel, and other matters.[1]

Departmental Organization

The organization of the X-ray departments which Major Reavis visited in his tours varied widely. In general hospitals, the department was usually well organized, with a radiologist, one or more associates or assistant radiologists, and a sergeant who acted as chief technician and supervised several other technicians. In these general hospitals, radiology was a specialty and the tables of organization designated the radiologist as chief of his service and responsible only to the commanding officer.

In some station hospitals and in many evacuation and field hospitals, the situation was often very different. In some of these hospitals, the department was conducted by an officer whose radiologic duties were secondary to his other duties and who might have only part-time help from enlisted men. In some hospitals, there was no professional supervision at all; the technician took the radiographs and the surgeons or others who had requested them made their own interpretations.

In many of the hospitals just described, even when radiologists were assigned to them, radiology was considered a minor specialty and the radiologist was responsible to the chief of the surgical service and not to the commanding officer. In a number of instances, Major Reavis discussed this matter with the commanding officer of the hospital, who almost always was agreeable to making the radiologist directly responsible to him. The arrangement was never officially altered, however, though Major Reavis always reported the hospitals in which it was in effect to the chief of the Professional Services Division, Headquarters, Surgeon, SOS, SWPA.

Although Major Reavis considered it essential that radiology be an independent service in all hospitals, he found that whether it was or was not, radiologists experienced very little interference in their duties, administratively or

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[1] These reports to the Area Surgeon, which are on file in The Historical Unit, U.S. Army Medical Service, Walter Reed Army Medical Center, Washington, D.C., 20012, constitute the most complete source of information available concerning radiology in the Southwest Pacific Area in World War II. Unless otherwise indicated, the specific data in this section of this volume are derived from them.

professionally. Almost always, the radiologist in charge organized the department, directed its functioning, utilized his space and equipment as he wished, and made such improvisations as he considered necessary to replace the items of equipment that were not attainable. Such independence was highly advantageous if the radiologist was well trained and experienced. On the other hand, it put him in a highly disadvantageous position if his training was little more than a short course in an Army school or if he had had no training in radiology at all.

General Observations

By the end of his first tour of inspection, Major Reavis had made a number of concrete observations:

1. On the whole, radiologic sections in the SWPA were performing a valuable service to the Army and the Medical Corps. When the conditions of operations, the numerous defects in the system, and the lack of any organized coordination were considered, the quality of service could be classed as commendable. There could, of course, be no fair comparison between the operation of an X-ray department in a forward tropical area of combat and a similar department in the Zone of Interior.

2. Few medical officers with radiologic training were available. The officers without training who were assigned to the radiologic service were putting forth an earnest effort and doing a fairly good job, but practically all of them would benefit by a period of intensive training of from 30 to 60 days in a general hospital.

3. All departments inspected had at least one good enlisted technician. These men were of great value in the proper handling and maintenance of equipment and in the general functioning of the department. In fact, exclusive of film interpretation, these technicians, in many instances, had a better basic knowledge and understanding of the fundamentals of radiology than did the nonradiologic officers under whom they served.

4. The quality of fluoroscopy and of film interpretation was directly proportional to the training of the medical officers in the departments of radiology. Numerous incorrect interpretations were observed (p. 587).

5. The number of films used was unduly large. It probably could be reduced considerably by increasing the ability of the medical officers responsible for their interpretation.

6. A general laxity was observed in the use of cardboard holders. This was an important matter. Screens were wearing out rapidly, replacement was uncertain, and wear and tear on them could be reduced materially if paper folders were used.

Even his preliminary observations convinced the Acting Consultant in Radiology that the efficiency of departments of radiology could be greatly increased if two conditions were met:

1. The radiologic services in the area must be better coordinated and organized.

2. Facilities must be established for servicing, maintaining, and repairing radiologic equipment.

RECOMMENDATIONS

As the result of his observations on his first tour, Major Reavis made the following recommendations concerning a consultant system in radiology in the SWPA:

1. A system of base section or area consultants should be inaugurated, in order "to establish and maintain a relatively high standard of radiologic service technically and particularly professionally."

2. In each base, there should be supervision of all the X-ray departments in the base. The installations were too numerous and trained radiologists in too short supply to permit placing a trained radiologist in every hospital. Practically every base section, however, had at least one trained radiologist in it. It would therefore be practical to assign a radiologist in each base as the base radiologic consultant, in charge of all X-ray work within that base. Preferably, he would be a diplomate of the American Board of Radiology. He should be responsible for the quality of all X-ray work in the base, his report to the Area Surgeon being submitted through the chief radiologic consultant at headquarters.

3. The position of base consultant would require a medical officer of great diplomacy. It would be necessary for him to deal with the base surgeon, the commanding officers of all hospitals in the base, all radiologic officers in the base and all medical officers doing radiologic work, and various members of the staffs of all hospitals. He would also require the cooperation of all those listed, to better the general care of the sick and wounded.

4. The base consultant should visit each X-ray department in the base at least once a week. His visits should be more frequent if there was greater need for his services in any particular installation. He should supervise the functioning of X-ray sections, read all difficult films, and do the fluoroscopy in the institutions in which there were no trained radiologists.

5. The base consultant should be assigned to one of the larger hospitals in the base, out of which he would operate as chief radiologist for the entire base. In other words, he should conduct his operations by the principle used in large civilian practices, by which one physician is in charge of the X-ray departments in several hospitals and supervises the work in all of them, though each department has its own radiologist.

6. It would be desirable for the base radiologist to be responsible for the maintenance of equipment. He should also work in cooperation with the service groups to be established to solve other pressing problems of equipment (p. 625).

7. The base consultant should be responsible for the establishment and

maintenance of one or more X-ray units for radiation therapy. These units should be set up at whatever hospital or hospitals he thought best, but they should be used only for therapy and he should supervise all treatments.

Major Reavis listed the names and present locations of the radiologists in the SWPA whom he considered qualified for appointment to specific bases. He emphasized in his report that he considered some such system as he had proposed not only practical and desirable but absolutely essential.

The system proposed was never put into effect or even officially mentioned, and no base consultants in radiology were ever officially appointed. In a number of instances, however, a completely unofficial but highly practical system evolved on a personal basis: Radiologic officers in the bases, with little or no training in this specialty, made contact with more experienced radiologists nearby, who helped them in the solution of their problems. In his tours, Major Reavis frequently found this situation in effect. Maj. (later Lt. Col.) Dan Tucker, MC, of the 9th General Hospital, for instance, helped to set up X-ray departments in several station hospitals, including one on Goodenough Island and one in Hollandia. He helped the Navy with installations on Owi Island in New Guinea and on Biak, where he also helped install X-ray equipment in an Australian field hospital. The radiologist of the 4th General Hospital, similarly, provided technical aid and consultation for a number of adjacent hospitals on Luzon. In these and other instances, however, it was the initiative of individuals and not official action that provided good X-ray service under extremely adverse conditions.

PREPARATION OF TECHNICAL MEMORANDUMS

One of Major Reavis' early clinical observations was that backache was an extremely common complaint among troops in the SWPA (p. 696). Many patients were received at the 42d General Hospital with this complaint, and the diagnosis of spondylolisthesis was notably confused and unsatisfactory. With this background, he paid special attention on his tours to spinal radiology, and his more detailed observations confirmed those he had made earlier.

To clarify the clinical confusion, Major Reavis prepared a technical memorandum dealing with spondylolisthesis (p. 669) and submitted it to the Surgeon, through the chief of the Professional Services Division, for distribution to the radiologic services of the various hospitals. Similar memorandums were prepared on duodenal ulcers, fractures of the skull, fractures of the ankle, wounds and lesions of the chest, and a number of other conditions.

Whether these memorandums were universally distributed is not known. In view of the great distances and poor communications, it is highly doubtful that all installations in the area received everything that came from a single headquarters.

LIAISON

As in other theaters, liaison was one of the functions of the Acting Consultant in Radiology, and he interested himself in it and fostered it during his period of service.

Other Services

His relations with the Navy were generally cordial, as were those of other radiologists. When the 17th Station Hospital was in the Milne Bay area, where there was a heavy concentration of Navy personnel, all necessary care, including radiologic care, was provided for them at this hospital. Similar situations occurred in other locations. Navy Seabees were always helpful in construction work and repairs when logistics made their cooperation practical.

Australian Services

There was no formal radiologic liaison with Australian medical officers, but contacts were established with the Australian radiologists and were maintained on a cordial personal basis.

There were numerous illustrations of these relations. One U.S. Army hospital, for instance, used Australian equipment while it was in Australia. The radiologist was also able to obtain the services of a radiation physicist from the University of Melbourne to calibrate his machine for therapy. In reverse, Australian radiologists were in very short supply and films from their hospitals were frequently read in U.S. Army hospitals (p. 649). They reciprocated by obtaining books and other items for U.S. hospitals. The 4th General Hospital, while it was set up in Melbourne, had excellent liaison with the Kelly Radium Institute.

While the 118th General Hospital, the Johns Hopkins Hospital affiliated unit, was set up near Sydney, it operated in two sections, one of which utilized space in the Royal Prince Alfred Hospital. The X-ray department of the U.S. hospital had the exclusive use of a certain amount of space in the main X-ray department of the Australian hospital. U.S. equipment was installed in this space, and a time schedule was arranged to permit the facilities to be used by both U.S. and Australian medical officers without complications. When complicated studies were required or when X-ray therapy had to be given, U.S. patients had to be sent by ambulance from the other section of the 118th General Hospital, which was then utilizing part of the Hydro Majestic Hotel at Medlow Bath to the Royal Prince Alfred Hospital near Sydney. A round trip of 140 miles was involved. In May 1943, the two sections of the 118th General Hospital were combined in newly constructed buildings at Herne Bay.

While Major Reavis was Acting Consultant in Radiology, SWPA, he had most rewarding contacts with Dr. A. G. S. Cooper, Director of the Queensland Radium Institute, who was then in charge of the radiology service at the Brisbane General Hospital (fig. 192). This was the largest general hospital

FIGURE 192.—Capt. Joseph L. Morton, MC, radiologist at the 4th General Hospital, and Dr. A. G. S. Cooper, Director of Radiology, Brisbane General Hospital.

south of the Equator, and from the radiologic standpoint, it was excellently equipped and staffed. Consultations on interesting cases were held with Dr. Cooper, as well as with the radiologist at the Greenslopes Australian Army General Hospital in Brisbane.

At the close of the war, Dr. Cooper wrote Major Reavis as follows:

I know that my colleagues and I will always remember the wonderful clinical meetings that were put on at both your naval and army hospital establishments, mostly on a Sunday morning. Clinical material was so ably presented by your medical officers, and then again at the close of the meeting there was often a repast including all the items which were in short supply in our rationed households!

On my own side, I was a Radiologist in New Zealand when the war broke out and wrote to Sydney, my home city, volunteering for active service as a M.O. The Army authorities advised me to come to the Brisbane Hospital post, from where I could be enlisted at a few days' notice. If I recall correctly, the first diagnostic X-ray unit sent out with American forces was lost with shipwreck close to Brisbane and for some months I was helping out your units which were first to arrive in that direction. You will remember when therapy was first brought here. I do not think it was until early 1943 and in the intervening periods I carried out all the therapy required for your forces in the South Pacific Area. I had many contacts, including one with Major Paul McDaniel, formerly Physics Professor in Alabama, and he arranged supplies of radioactive phosphorus from Lawrence in Berkeley during 1944, during a time when I think there was no P–32 used in the rest of the British Commonwealth.

Other Allies

In the last quarter of 1944, personnel of the 27th General Hospital assisted in planning the X-ray department of the Netherlands East Indies Hospital, Kotanica, and also instructed nurses in X-ray technique.

Extremely cordial relations were established with the Philippine Army Medical Department, as well as with civilian physicians, once contacts were made after the islands had been reoccupied.

MEETINGS AND CONFERENCES

Some hospitals, particularly affiliated units, had journal clubs and study clubs in which the whole staff participated. At the 42d General Hospital, the X-ray department held weekly conferences at which interesting cases were presented and which were followed by ward rounds for bedside discussions. This hospital also had monthly staff meetings and a number of medical symposia, which were frequently attended by Australian physicians. On all his hospital visits, Major Reavis made it a point to encourage such meetings and conferences.

Several interhospital societies were formed, including the Island Radiological Society and the Manila Roentgen-Ray Society.

These activities were well worth while, but it should be noted again that they were all the result of individual initiative. In view of the lack of a consultant system in radiology during the entire war, as well as of a planned radiologic organization, it was scarcely surprising that there was no official sponsorship of any sort of meetings, in spite of their proved value for training and other purposes in other theaters of operations.

MEDICAL LITERATURE

The supply of medical literature was inadequate and erratic, which was unfortunate. It was needed for training purposes, and it would have done much to relieve the tedium of periods without professional occupation.

Most units that came over early in the war had no library facilities at all. A few of the larger general hospitals, as well as a number of smaller units, later secured texts by issue from medical supply or by purchase in Australia. Major Reavis noted on his tours that while one hospital might have an excellent supply of books, another would not have even those that could be secured by general issue. Their possession, again, was a matter of individual initiative, or lack thereof.

A number of units, though by no means all, had War Department Technical Manual 8–275, the technical manual dealing with X-ray technique (*1*). Major Reavis recommended that copies be issued at once to all installations that did not possess them.

Almost none of the hospitals had any texts on radiology except for the handbook that was packed with each field X-ray unit. Major Reavis recommended that copies of Sante's manual (*2*) be issued to all hospitals, and that all X-ray departments secure such other radiologic texts on technique and interpretation as could be procured through normal supply channels. This was the only feasible method; there were no medical bookstores in the jungle and very few in the whole SWPA.

As time passed, many hospitals began to receive medical journals on a regular basis, and a number built up reasonably satisfactory libraries, particularly in respect to periodicals.

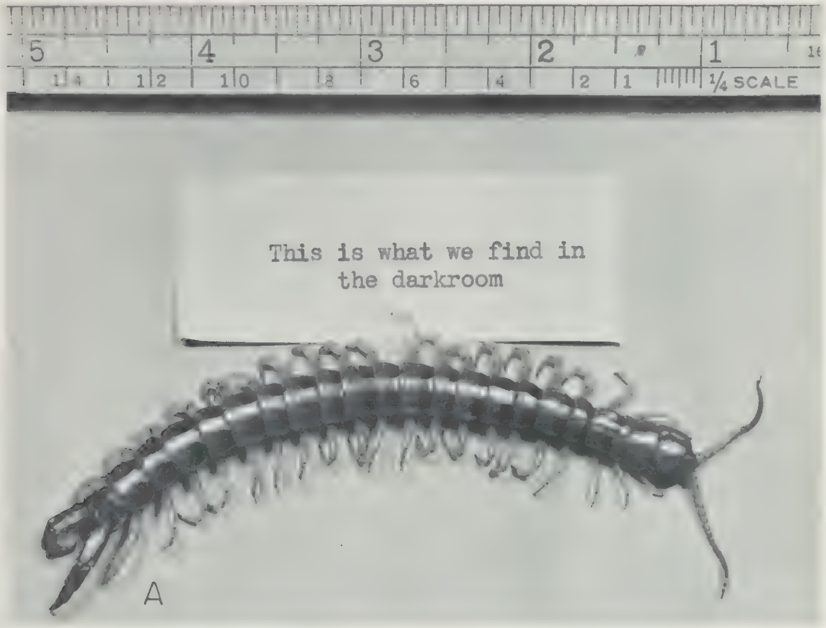

FIGURE 193.—Insect and animal life encountered in SWPA. A. Type of insect found not only in darkrooms but in other areas about camp.

Many medical officers procured their books and journals personally. Maj. Joseph L. Morton, MC, for instance, by the time he reached Milne Bay, had several footlockers of books and periodicals, some sent to him from the United States and some purchased in Australia. With this supply, he was able to set up a library of sorts for the whole hospital.

Books did not hold up well in the Tropics. They soon became moldy, and the musty odor of the texts he used in the SWPA, Major Morton wrote, still lingers about them many years after the war.

ENVIRONMENTAL CONSIDERATIONS

There was, of course, nothing to be done about the environment in which radiologists worked in the Pacific Ocean areas, but it was a factor that the Acting Consultant in Radiology constantly had to bear in mind as he moved from installation to installation. It explained some poor radiography, and it also explained some personality difficulties. Among its components were the climate; the plague of insects and snakes (fig. 193); the risks of contact with the diseases of the natives and the unsanitary environment in which so many of them lived; and the psychologic considerations inherent in the factors just mentioned and in the whole way of life in wartime, including the sheer boredom of the hours that were not occupied with work.

FIGURE 193.—Continued. B. Boa constrictor killed at 51st General Hospital in Milne Bay.

Climate

The extreme heat and very high humidity characteristic of other parts of the Pacific Ocean areas were also present, often in an even greater degree, in the Southwest Pacific. The combination was physically debilitating, and, as pointed out in detail in several places in this section, it made for numerous mechanical difficulties in the operation of an X-ray department.

In the opinion of every radiologist who worked in the SWPA, his own particular location was the most rain-saturated area in the world. In some places, the rainfall amounted to 300 inches per year. In some, it rained as much as 14 to 17 inches in 24 hours. The characteristic pattern was sudden, torrential downpours, lasting from 10 minutes to as many hours, and leaving in their wake thick, adhesive mud. Flooring was usually available only for the surgical, X-ray, and supply tents and for the wards with the most seriously ill casualties. Mud was tracked into the tents, and the flooring and ground inside were sometimes as muddy and soggy as the ground outside. When the

rain was particularly heavy, a fine mist seeped through the roofs of the tents, and men learned to sleep with their bedding rolls over their heads, to avoid the nerve-wracking experience of having water drip on them all night. Among the troops, any brief respite from the heavy downpours came to be known as the dry season.

The incessant rain had the same deleterious effect upon morale as it had upon clothing and equipment. When it was combined with daily temperatures of 90° to 100° F. and higher, it introduced psychologic as well as physical problems.

Insects and Other Animals

Mosquitoes, flies, and other insects were a constant nuisance, and worse, in New Guinea, the Philippines, and other islands of the Southwest Pacific. Snakes were also often encountered. Wire screening was always in short supply, and what was available had to be used in the mess tents and other essential areas. Only a few units were able to obtain sufficient screening to protect all the open areas of their X-ray sections. The use of mosquito netting at night was obligatory. In some areas of New Guinea, the flapping of large fruit bats against the netting could be heard all night. In the morning, scorpions and colonies of ants had to be dumped out of one's shoes.

Most of the prisoners of war released in the Philippines and in Japan were infested with fleas, which were the size of a matchhead (about 3 mm.) and which jumped with a recoil animal fleas do not equal. They were readily eliminated with DDT dust guns.

Psychologic Considerations

Since most hospital units spent a considerable part of their time staging, and since the workload, even in combat areas, was often extremely unequal, radiologists, like other medical officers, often found themselves with time on their hands. What to do with it was a problem, and boredom was a terrific psychologic factor. The recreational facilities supplied were, naturally, limited. Most groups had access to areas cleared from the jungle for softball and other sports, and moving pictures were shown regularly, but the simple, normal recreations of civilian life were completely impractical. The situation affected morale, and poor morale affected performance.

To understand the situation in New Guinea, for instance, it must be remembered that, next to Greenland, it is the largest island in the world and that, even in 1965, there are many areas that have never been explored by white men. Theoretically, a stroll through the woods would have been pleasant. Practically, it was not feasible. Large green pythons and other poisonous snakes inhabited the jungle, together with the giant lizards so common in New Guinea. One radiologist still remembers how, on a moonlit night, he entered the officers' quarters and encountered a 4-foot iguana.

There was another reason for not straying far from the compound, even when it was not specifically forbidden: An area might be secured technically, but Japanese might still be close by. They were a tenacious foe, who did not believe in surrender. They would hide out in caves and forage for food, and it was well not to chance an encounter with them.

The proximity of the sea did not provide much recreation, for it too had its dangers. The coral that abounds along the shores of South Pacific islands is sharp and cuts like a razor. Sharks in these waters are unusually ferocious, and they congregated in waters in which refuse was dumped from ships. Swimming was therefore not a safe sport.

It was thus the business of medical officers to provide their own occupation, and they tried all sorts of things to fill up their spare time. One group occupied themselves for many days grinding lenses for telescopic systems to study the heavenly bodies, a particularly fascinating hobby in this part of the world, where the Southern Cross could be beautifully demonstrated in these skies. Photography had possibilities, but they were necessarily limited. Films had to be sent from the United States unless one could obtain them from the Signal Corps. In addition, films developed in X-ray solution were often disappointing. Nonetheless, when material could be procured, many radiologists cultivated this hobby. Bridge, poker, and other games also helped to pass the time.

Finding occupation was especially hard for the radiologists assigned to isolated hospitals in which a radiologic service had to be provided but in which there was really very little work. In view of the circumstances, it is surprising that in these hospitals, as in others, personality clashes were as infrequent as they were.

PROTECTION OF PERSONNEL

In all of his visits to medical installations in the SWPA, Major Reavis investigated in detail the measures taken for the protection of personnel. In his final report to the Area Surgeon, through the chief of the Professional Services Division, he stated that these measures were generally inadequate, though in most hospitals, particularly those in which there were trained radiologic personnel, many improvisations indicated the natural aptitude of men for doing the best they could with what they had available. In the numerous installations in which departments were set up in tents, protection was almost entirely a matter of improvisation.

The need for protection against radiation varied according to the volume of diagnostic work, the number of fluoroscopies, and the amount of therapy given. The need for protection in small X-ray sections was not at all comparable to the need in large, active hospitals, in which 50 to 100 diagnostic examinations were made daily, or in hospitals in which radiation therapy was administered. In these larger units, however, a trained radiologist was usually in charge, and he improvised whatever protection he thought was necessary.

It was in the small units, in which the load was less sustained, that the need for protection was most urgent and was not always forthcoming.

Conventional Protection

Major Reavis recommended immediately that sheet lead be supplied to all installations in which X-ray units were used, diagnostically or therapeutically, and that, whenever possible, all walls behind which personnel worked should be covered with sheet lead of 1-mm. thickness for a height of 8 feet. He also recommended that sheet lead of the same thickness be furnished to line the walls of rooms in which personnel were in constant attendance on X-ray units. It was almost the end of the war before material was provided for this provision to be carried out.

A few hospitals that came into the Pacific early in the war had sheet lead in their equipment (fig. 194). Later in the war, just before the Japanese surrender, this item was received in such quantities that most units were able to obtain it, but this was the old story of locking the barn door too late.[2]

Units that had sheet lead generally used it wisely; that is, if quantities were limited, they first of all made shields for their technicians to stand behind during exposures.

Until sheet lead could be obtained, other materials were used. Sheet tin used for roofing provided considerable protection and a number of hospitals employed it. The 80th General Hospital, having no lead, used 10 thicknesses of sheet tin in front of the control room panel and around the X-ray machines. Later, this unit obtained enough sheet lead 0.5 mm. thick to line a single X-ray room.

Sand was used in various ways. Some hospitals employed sandbags. In the Philippines, Maj. Morton Helper, MC, found that excellent protection could be obtained by filling with sand tins that had contained developing powder and stacking them on top of each other until a protective wall of the desired height and width had been built. A second thickness of cans, staggered to cover the holes in the first thickness, was then added. A sturdy wooden retaining frame was erected to maintain the stability of the rows of

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[2] Major Morton recalled an amusing experience in connection with the procurement of lead sheeting. When he was assigned to the 4th General Hospital in Townsville, Australia, it was at first almost impossible to secure it in sufficient protective amounts. Sometime later, after enough had been received for proper protection, he received a letter from a supply officer asking how much lead sheeting he wished. Since the department already had all it needed, Major Morton did not reply. Within a few days he received another, similar letter, this time with the red border that indicated that an immediate reply was required.

It was not until some months later that the explanation was forthcoming: A certain radiologist in a dispensary in Brisbane, unable to get the lead he needed by requisition, decided, since the base section commander's office was immediately over the X-ray department and his desk and chair were immediately over the X-ray unit, that it would be only proper to check into his safety. He therefore attached an X-ray film to the under side of the chair and found, when he removed it, that it was completely black. Thereafter, so the story went, there was no difficulty in securing lead for any installation in this base. In fact, the base section commander became rather a nuisance about it.

There was a good deal of speculation, of course, about how many below-upward shots had been needed to produce so much X-ray scatter on the day the test was made.

FIGURE 194.—Unrolling sheet lead to be used for walls of X-ray department of 105th General Hospital at Gatton, Australia, January 1943.

cans. Discarded metal cans of this size or any other could be used for this purpose, but the uniform size and straight sides of the powder cans made them particularly convenient.

At the 9th General Hospital, Major Tucker and Capt. (later Maj.) Arthur J. Tillinghast, MC, also used sand, but in a different manner (*3*): Clean, dry sand from the beach was packed between the wall of the building and a retaining framework to a height of 7½ feet. The hydrostatic pressure of the sand made it necessary to use very strong retaining partitions, which were constructed of studs cut from ship's dunnage, interlocked with packing box wire and covered with building paper, wire netting, and pressed wood (fig. 195). The retainers were spaced 10 inches apart, so that there were 9 inches of sand at the studs and 10 inches in the intervening spaces. Subsequent direct exposure tests and film tests on technicians indicated that protection was entirely adequate.

Sufficient lead was available at this hospital to place a shield 3½ by 7 feet in each radiographic room and to construct lead-backed doors for this room and the fluoroscopic room, so hung that the sanded walls overlapped the lead.

Other Precautions

Trained radiologists, as well as a number of untrained men, put into practice the inverse square law, that intensity of radiation is inversely proportional to the square of distance. In other words, they simply utilized distance as a means of protection from radiation, by lengthening the cord of the exposure timer.

Protective gloves and lead aprons were provided, but they deteriorated

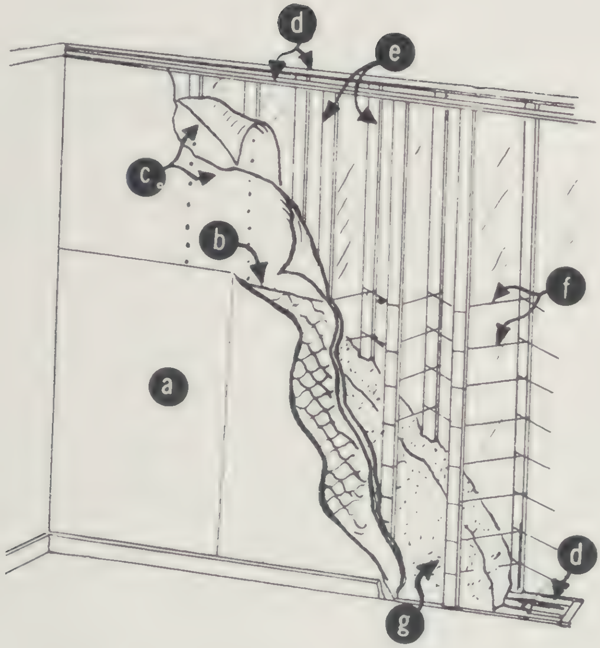

FIGURE 195.—Construction of protective walls in X-ray department, 9th General Hospital, SWPA (3): pressed wood (a), wire netting (b), two layers of building paper (c), 1- by 2-inch plates (d), 1- by 2-inch studs (e), reinforcing wire (f), and 10 inches by 7½ feet sand (g). Cutaway view shows components of protection.

rapidly in the extreme heat and humidity, and they were frequently not used because they were heavy and hot. As a compromise, the lead aprons were laid across chairs and the technicians stood behind them.

X-ray departments were most efficiently operated when technicians were assigned to them on a permanent basis. Major Reavis therefore discouraged the plan used in some hospitals, for protective reasons, of keeping technicians in the department for 2 or 3 months and then assigning them to other work for the next 2 or 3 months. On the other hand, each man was given as much time off as was feasible and consistent with the proper functioning of the department. In one properly run department, only real emergencies were permitted to interfere with the 90-minute lunch period (which also had the advantage of permitting ventilation of the fluoroscopic and processing rooms and cooling off of equipment). Even when the workload was greatest, every endeavor was made to keep duty hours for the technicians at 40 per week and to reduce them to 35 whenever this was possible. It was also the policy in most hospitals to rotate technicians for night emergency duty.

Monitoring

Monitoring of personnel was generally given very little consideration in the SWPA, especially in departments directed by medical officers with little or no training in this specialty. Major Reavis recommended to the Area Surgeon, through channels, that a memorandum be issued directing that all X-ray personnel have red and white blood cell counts and hemoglobin determinations every month and that any abnormality in the white blood cell count, whether an increase or a decrease in number, should be considered an indication for a differential count.

In a number of hospitals, X-ray personnel routinely wore dental films with a paper clip or lead marker attached. These films were checked periodically to determine the degree of exposure.

At the 80th General Hospital, in which roofing materials were used for protection, complete blood studies were performed on all personnel on the first and fifteenth of each month. Either protection was not entirely adequate or some technicians were careless, for on two occasions, because of lowered red blood cell counts and lowered hemoglobin values, it was necessary to provide a week's rest from departmental duties for certain men. The load at this hospital was about 1,250 examinations per month, with an average of 3 exposures per examination. Daily fluoroscopic examinations consisted of four gastrointestinal series and two barium enemas.

It was Major Reavis' considered opinion that no one in the SWPA received an excess dosage of radiation from either diagnostic or therapeutic work with X-rays. This was true of both professional and technical personnel. One medical officer was rumored to have suffered from overexposure of his fingers during fluoroscopy. Major Reavis had cautioned all radiologists that fluoroscopic examinations should be limited to the gastrointestinal tract. Foreign body localization could be done more accurately by radiography, and fractures should not be set under the fluoroscope.

A higher incidence of skin infections was observed in X-ray personnel than in the hospital detachments generally. This was attributed to the time spent in the hot, humid atmosphere of the darkroom. The incidence was considerably reduced whenever ventilation was improved.

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CHAPTER XXVIII

Professional and Technical Personnel

Charles W. Reavis, M.D.

PROFESSIONAL PERSONNEL

Shortages

At the beginning of World War II, radiologists were in short supply in the United States. As more and more hospitals were formed, military and civilian shortages became increasingly acute. They existed even in the Mediterranean and European theaters, which were being given the preference, and they were pronounced throughout the war in the SWPA (Southwest Pacific Area) and other areas in the Pacific.

A few hospitals in the SWPA had Board-certified radiologists on their staffs. Others either had less qualified radiologists or had officers in charge of radiology who had no training beyond the short courses given in Zone of Interior Schools (p. 30). At this time, the Army was still apparently working on the principle that any medical officer could do anything in the whole field of medicine. Otherwise, it would have been hard to say why some radiologic assignments had been made in the hospitals that went to the Pacific. Some of those assigned had some slight interest in this specialty because it was related, directly or indirectly, to their special fields of endeavor. This was usually true of the heads of surgical services, who rather frequently were also in charge of radiologic services. Many other officers, however, were probably assigned for the simple reason that there was no one else to assign (these were the so-called radiologists by act of Congress). Most radiologists in this group happily relinquished their duties as soon as others with more interest in the specialty, even with no more training in it, became available.

When the 4th General Hospital arrived in Australia in 1942, it had two certified radiologists, Maj. (later Lt. Col.) Eugene Freedman, MC, and Capt. (later Maj.) Joseph L. Morton, MC. By February 1944, there were 11 certified radiologists serving in radiology in the SWPA, including, in addition to Major Freedman and Captain Morton, Maj. Wilbur S. Brooks, MC; Capt. Meyer Cohen, MC; Capt. Daniel L. Doherty, Jr., MC; Lt. Col. (later Col.) Whitmer B. Firor, MC; Maj. Donald B. Fletcher, MC; Capt. E. M. Holleb, MC; Maj. Charles W. Reavis, MC; Maj. Maurice R. Richter, MC; and Lt. Col. Dan Tucker, MC.

In April 1944, there were also in the SWPA six radiologists with 3 years of formal training, three with 2 years of training, and six with 1 year of training. At this time, there were 86 hospitals that required radiologic service (15 general, 57 station, 6 evacuation, and 8 field hospitals). Those whose X-ray sections were not staffed by the 26 trained or semitrained radiologists just listed were cared for by medical officers with no radiologic training at all or with training up to 8 months and varying widely in quality.

In all, 139 radiologists served in the SWPA during World War II. Of the 79 who were Board-certified, the great majority came into the area after April 1944 and most of these after April 1945. It is an interesting fact that 44 noncertified medical officers who served in radiology in this area during the war continued in their specialty on their return to civilian practice and were later certified by the American Board of Radiology.

Training

As part of the radiologic program in the SWPA, a number of medical officers were sent to the 42d General Hospital, near Brisbane, late in 1943 and during 1944 for more or less extended periods of additional training. They were selected by the Acting Consultant in Radiology on the basis of his evaluation of their ability as he encountered them in his tours. Among these officers were Capt. (later Maj.) Horace W. Doty, Jr., MC, 27th Portable Surgical Hospital; Maj. Leonard S. Ellenbogen, MC, 5th Field Hospital; Maj. Alton S. Hansen, MC, 92d Evacuation Hospital; Maj. (later Lt. Col.) Herbert D. Hebel, MC, 1st Evacuation Hospital; Lt. David V. Mann, MC, 105th General Hospital; and Capt. Bennett W. Muir, MC, a highly trained ophthalmologist who was in charge of the X-ray section at the 172d Station Hospital. A number of other radiologic officers without previous training of any significance were also sent to the 42d General Hospital to gain radiologic experience.

The training program greatly improved the efficiency of fluoroscopy and the diagnostic performance in the SWPA. It also resulted in a considerable reduction in the number of films used, a factor that is always related to the amount of training radiologists have had.

Assignment

One part of the personnel problem in the SWPA was, as just pointed out, a shortage of personnel. Another part had to do with efficient use of such personnel as were available.

There were often sound reasons for the detachment of radiologic personnel from the hospitals to which they were originally assigned, one of them being the necessity of providing medical care, of which radiology was a phase, for numerous small hospitals, which were often separated from each other by hundreds of miles of water. On the other hand, there was often

poor utilization of the radiologic talent that was available in the area, whose assignment and utilization frequently left much to be desired:

1. The basic fault was that there was no overall organizational plan for radiology in the SWPA, and failure to appoint a full-time consultant who had any authority (p. 566) meant that this trouble was never overcome.

2. Occasionally, radiologists spent all or a considerable part of their time engaged in nonradiologic duties. One Board-certified radiologist served for a time as a receiving officer, another as a sanitation officer, and a third as a venereal disease officer. In addition, it was inevitable, because of the shortage of engineers and because X-ray departments require special construction, that radiologists assumed these and other duties.

3. It was a frequent and serious error to send qualified military personnel to the SWPA and keep them in staging areas, without occupation, for long periods of time. During his tours, Major Reavis found, in casual conversations, several medical officers who had been in the Pacific for up to 2 years without ever having seen a patient. He observed that in some staging areas, many radiologists, either acting on their own initiative or acting through their commanding officers or through base section headquarters, had obtained temporary duty at active hospitals nearby. They thus overcame one of the most serious problems in the Pacific Ocean areas, boredom from inactivity, and at the same time helped to overcome the waste of qualified personnel.

4. Major Reavis also encountered hospitals operating without trained radiologists and other personnel while in the same general areas, or on the same island, two or three hospitals might be staging with their radiologic personnel, some of them well trained, completely idle. In a number of instances, he recommended that these idle officers be assigned to temporary duty in the hospitals operating without radiologists and that other officers, with limited training be sent to general hospitals for further training during such periods of idleness.

5. There were frequent gross discrepancies between the qualifications of the professional radiologic personnel and the size, and therefore the requirements, of the hospitals to which they were assigned.

Major Reavis stated frankly in his report on his first tour of inspection that unless his recommendations as to base (regional) consultants were put into effect (p. 570), a redistribution of radiologic assignments would be advisable. Such a redistribution was never effected, but, as already noted, he was pleasantly surprised, when studying source material for this volume, to find that a considerable number of the changes he had recommended had been carried out. It is now (1965) his opinion that had he remained longer as Acting Consultant in Radiology, or had a replacement been appointed when he was returned to the mainland, many more of his recommendations would have been carried out. There was, however, no replacement for him, and many recommendations were therefore simply forgotten or ignored.

Recommendations.—Major Reavis made the following specific recommendations about the assignment and utilization of personnel:

1. In each general hospital there should be one well-trained radiologist, assisted by two medical officers in training. When these two officers were regarded as sufficiently trained, they should be sent as radiologists to smaller installations and replaced by two other officers whose radiologic training was limited or who had had no training at all.

This recommendation, which was not carried out, would have helped solve the problems of smaller units without any radiologic coverage at all. At one time during Major Reavis' tour of duty as Acting Consultant in Radiology, he had requests from 11 small hospitals for such coverage. He made recommendations concerning this matter in his final report.

Some temporary assignments were made to solve such shortages. When, for example, the 132d General Hospital arrived at Oro Bay, New Guinea, in May 1944, it did not function at once, and the radiologist, Maj. Egon G. Wissing, MC, was attached on temporary duty to a small hospital in the vicinity that had X-ray equipment but had never had anybody on the staff qualified to use it. Major Wissing set up a small X-ray department and left it in efficient functioning order.

2. In larger installations, with very active X-ray services, it would be helpful to assign a Medical Administrative Corps officer as an administrative assistant to the radiologist, thus permitting him to devote practically all his time to his professional duties. As matters stood, the radiologist had to spend a considerable part of his time in paperwork and other administrative duties. This recommendation was not carried out.

Reassignment Problems

In the SWPA, as elsewhere, considerable diplomacy was required to effect transfers. Many of the units in the area had served together as groups during preliminary training or were affiliated units, which were always solidly united. When these units were sent initially to isolated areas, where they had little contact with other groups, their bonds of union became even stronger.

Many of the units, particularly the affiliated units, simply had too much radiologic talent to be permitted to retain it all, though to effect changes was a delicate matter. At the same time, the hospital commander had to be persuaded to agree to the changes desired, so that direct orders for the transfer could be requested from headquarters. Much of the work done by Major Reavis along these lines was verbal, personal, and never officially recorded.

It was occasionally necessary to transfer radiologists from one hospital to another for personality reasons alone, without regard to qualifications or competence. In one station hospital, for instance, a well-trained radiologist simply did not get along with other members of the staff. So deepseated was

the conflict that Major Reavis was told frankly that the staff had no confidence in this officer's work and that the department functioned better when it was run by a member of the surgical section. Since the same information was received separately from the chiefs of both the medical and the surgical service, the commanding officer of the hospital, and the base surgeon, Major Reavis accepted the situation as it was reported to him and recommended the removal of the officer in question and his assignment to temporary duty elsewhere. He was not returned to his own hospital during the war. Other similar situations were handled in the same manner.

The Untrained and Inexperienced Radiologist

In his tours in the SWPA, Major Reavis often came face to face with problems created by the lack of trained radiologists and by the activities of untrained and inexperienced personnel placed in charge of sections of radiology. Many of these officers, considering the circumstances, did remarkably good work. Others did poor work, more often because of overactivity in a field in which they were ignorant than because of inactivity.

In one field hospital, for instance, some officers without previous training were attempting to make gastrointestinal examinations and gallbladder studies. The technicians in this hospital also had had no formal training. Major Reavis recommended that such refined examinations be stopped immediately and that X-rays be limited to those necessary for fractures and other trauma.

The inexperienced radiologist most often erred on the side of overreading; that is, because he was not well informed on the normal, he could not correctly interpret the abnormal. He was inclined to consider as abnormal any small deviation from his own mistaken idea of the normal. As a result, he diagnosed fractures, ulcers, and other pathologic processes that did not exist.

It was difficult to make inexperienced officers realize that, if one had to choose, an error of omission was better than an error of commission in the interpretation of a film. At that, one can hardly justify the advice that one unqualified radiologic officer was given by another without much more experience. He was told that 95 percent of all gastrointestinal series are negative—which is not too far from the truth—and therefore, if he reported all such series as negative, he would have only a 5-percent error. On the other hand, if he began to report positive findings, his percentage of error would increase materially. The solution, of course, was, as just indicated in another situation, to prohibit gastrointestinal and other delicate examinations by medical officers untrained in radiology.

Fortunately, the kind of positive mistakes made by inexperienced radiologists was usually obvious to experienced clinicians and consequently of not too much significance. Most casualties with conditions that required complicated study were, sooner or later, evacuated to general hospitals with trained radiologists on their staffs.

Under the circumstances prevailing in the SWPA, it is easy to understand that officers doing radiology overlooked more lesions than would have been overlooked in civilian hospitals. The quality of the films was much poorer than in civilian practice; equipment was less efficient; climatic and other physical conditions were adverse; and many officers serving as radiologists had had no training in the specialty. Most of the conditions overlooked were of no real significance, did not interfere with the patient's ability to perform as a soldier, and did him no real harm if treatment was delayed.

Duration of Service

Many medical officers assigned to the SWPA were overseas for almost the entire war. Replacements for key specialists were received slowly, even when the officers to be replaced were due back for rotation to the Zone of Interior. The area command, in view of the shortages of specialists in the area, were reluctant to release any of them; they wanted more such specialists, not replacements for them. For these and other reasons, rotation was never really effective in the SWPA, and radiologists were severely affected by this situation.

Medical officers who came over late in the war, particularly those who arrived in 1945, never really experienced the full flavor of jungle warfare. Even when they served in the jungle, they were not in it for very long, since demobilization began almost as soon as Japan surrendered.

The 4th General Hospital was not very active after it was assigned to the Philippines, and most of its officers spent their time on detached duty. In his report in October 1945, the commanding officer very correctly summed up the effects of long service in the SWPA:

> There can be no doubt but that prolonged service * * * places an undue physical and mental burden on personnel involved; and that these individuals possess unusual physical stamina and stability goes without saying—but many are close to the end of their tolerances. To force conscientious individuals to continue oversea duty up to the breaking point is neither in the interest of the service nor does it promote the welfare of the nation. Delays of several weeks' duration in poorly operated replacement camps do not benefit personnel who have already been overseas too long.

These remarks apply to a large proportion of the radiologists who served overseas in the SWPA.

Promotion

Promotions in the Medical Corps were extremely difficult to obtain in the SWPA. There were many reasons, including the interposition of numerous headquarters; the distances and mobility of the various units; and the inevitable introduction of personalities. Whatever the causes, many medical officers with excellent radiologic training and long experience deserved higher ranks than they ever obtained, and rank was therefore the same constant

FIGURE 196.—WAC technicians preparing patient for X-ray of chest, 334th Station Hospital, Hollandia, New Guinea, January 1945.

source of discontent among them that it was among other medical officers in the same situations.

ENLISTED TECHNICIANS

Enlisted personnel, including Wacs (fig. 196), who served as X-ray technicians in the SWPA deserve the highest commendation. Their devoted work contributed substantially to the radiologic service provided for the sick and wounded in this area. It was their task to produce radiographs of technical excellence, usually by a single exposure, because there would be no opportunity—or possibly no films—to repeat the study.

Some of these technicians had served in the same capacity in civilian life. Some of them had been trained in the Army schools in the Zone of Interior. Each of these groups served as a nucleus of knowledge and skill that they passed on to others with less training or no training at all. Some radiologic technicians without previous training were trained overseas by section chiefs. Some were sent for training to hospitals in the SWPA.

Several general hospitals and a few station hospitals conducted such courses. The 42d General Hospital had a school in Brisbane, in which courses lasted for 1 or 2 weeks or longer, as time and need permitted. When the 4th General Hospital was in the Philippines, it trained and graduated an average of four technicians each month.

The distribution of trained technical personnel was probably more equitable than that of trained officer personnel. Most hospitals had at least one technician with more or less training, and while shortages continued throughout the war, they were more often quantitative than qualitative. In fact, Major Reavis acknowledged that he often had the feeling, while surveying installations without trained radiologists, that the enlisted personnel knew more about what they were doing than the medical officers assigned to direct the department.[1]

The performance of these technicians was often remarkable. Major Morton related that at the 250-bed 12th Station Hospital, the five technicians assigned to it took care of all technical X-ray needs when a push was on and the hospital was expanded to 750 beds. He also commented on the excellent films they produced, even when the darkroom cooling system failed and the temperature of the solutions was far above acceptable levels.

X-ray technicians did a great deal more than make radiographs and develop them. They frequently obtained items of supply which their superiors could not (though often it was best not to inquire into how they got them). They helped construct hospitals. They did perimeter guard duty. They served as litter bearers and corpsmen. And they installed X-ray equipment, repaired it, and kept it working under extremely adverse circumstances.

It is unfortunate that tables of organization frequently did not give these technicians the grade to which their experience and their competent and devoted work entitled them. In some hospitals, as in the European theater (p. 360), radiologists and commanding officers awarded them stripes, even though the grades were not authorized, by juggling the total spaces within the organization.

OTHER TECHNICIANS

Until the Philippine Islands were reoccupied, no Army hospitals in the SWPA had civilian technicians. Then an attempt was made to employ them, and the same plan was used after the occupation of Japan.

The latter attempt was not very successful. Japanese technicians paid no attention to time or temperature, and their films were not satisfactory. The only Japanese who could speak English at the Tokyo General Hospital was

[1] That would not be impossible. Former Sgt. Russell J. Ernst, who served with the 42d General Hospital in SWPA, described his 3-month course at Letterman General Hospital as including instruction in:

1. Basic electricity (circuits, transformers, coils, rectifiers, etc.).
2. The theory of X-ray; types of machines, accessories and equipment; darkroom techniques (in a very well-equipped darkroom); film processing; and other practical work.
3. Anatomy, including study of the names and positions of bones on a skeleton.
4. The spelling and definition of medical, anatomic, and other technical terms.

Much of the second month of this course was spent in practical work on the machines and in the darkroom. Convalescent patients from the hospital were used as subjects, and each morning there was general class criticism of the films made the day before. Once a week, an emergency X-ray department was set up, with tent, Picker portable unit, and portable generator. The final month of the course was spent in practical work with the technicians in the X-ray section of the hospital.

There is a great deal here about which nonradiologic medical officers would know very little.

assigned to the radiologist, who used him as an interpreter to explain how film processing should be done. The technicians would bow, smile, indicate that they understood, and continue to turn out unsatisfactory films. Since radiographs found in the hospital when it was taken over were generally good, the impression was that the difficulty was not misunderstanding but lack of desire to cooperate.

CHAPTER XXIX

Facilities

Charles W. Reavis, M.D.

GENERAL CONSIDERATIONS

It was official policy in the Southwest Pacific Area that the fullest possible use be made of existing buildings that could be employed for hospitals. New construction was held to an irreducible minimum consistent with efficient operation, with the proper maintenance of equipment and supplies, and with the comfort of patients and personnel.

In line with this policy, existing buildings were used in Australia (figs. 197 and 198), and a few were again available after the Philippines had been reoccupied (fig. 199). In New Guinea and during island-hopping operations, hospitals were set up in prefabricated buildings or under tentage, or sometimes, in the jungle, with almost no protection (figs. 200 and 201).

Some units, especially field and evacuation hospitals, which went in early during landing operations, operated under tentage at all times. It was remarkable how rapidly X-ray service could be supplied in these landings. The 165th Station Hospital, for instance, arrived in Leyte Bay late in the afternoon of D + 1. Three days later, the X-ray department was in full operation on the beach, in a ward tent with a rough board floor. An adjoining tent was used for a darkroom and for processing films, and a fly tent was used to provide cover for three generators for the supply of electricity for the department. This was a very competent unit, with eight of its nine technicians fully trained in X-ray technique, and, in spite of crude conditions, it was able to handle a heavy workload. Its radiologist had had 3 years of training.

Regardless of the type of construction used for hospitals, an X-ray section required some sort of housing. Electrical facilities had to be protected, and film had to be handled and processed in a darkroom in which a supply of water was available. There could be no compromise with these requirements.

It was soon learned that X-ray departments did not function well when the equipment was set up on the ground, which usually was muddy. Concrete slabs provided the quickest and most satisfactory type of flooring (fig. 202), but they were not always practical: The floors installed in prefabri-

FIGURE 197.—Aerial view of Stuartholme, the Convent of the Sacred Heart, occupied by 42d General Hospital, Brisbane, Australia, from July 1942 to December 1943.

cated buildings in New Guinea were often too light to support heavy X-ray equipment. The support of the buildings depended upon unions held with bolts that were not machined, and they therefore became loosened with even the vibrations produced by walking.

It was the general policy to place the X-ray department as near the operating room as possible, particularly in forward echelons, in which combat casualties furnished the major workload. When portable buildings were constructed, the X-ray department was housed in a separate building located at a reasonable distance from other buildings in the unit, to avoid unnecessary radiation exposure.

AUSTRALIA

Hospitals set up in Australia during the early days of the war used existing hospitals as well as school buildings, convents and similar structures (figs. 197 and 198). The conversion of existing buildings was abandoned

FIGURE 198.—Gatton College, Queensland, Australia, location of 105th General Hospital. A. College building. B. Additional ward under construction, November 1942. Note pie tins used on top of pilings, to prevent destruction by termites.

after 1942, because the extensive remodeling frequently used so much time, labor, and material, all of which were in short supply. Because of the inadequacies of overland transportation, the policy was adopted of concentrating hospital facilities in or near the larger cities of the eastern seaboard, including Melbourne, Sydney, Brisbane, and Townsville. Standard U.S. Army designs for theaters of operations were altered to fit Australian conditions, and satisfactory buildings were produced, but the rate of construction was

Figure 199.—Locations of 49th General Hospital, Leyte, 1944–45. A. Front entrance of advance section, Tacloban, December 1944. X-ray department is to right of entrance. B. Aerial view of Jockey Club at San Lazaro Race Track, Manila, after conversion into hospital, 1945. C. View of hospital from center of race track. D. Another view of converted Jockey Club. The boy seen is sitting in one of the windows of the X-ray department.

so slow that the hospitals were sometimes not needed at all by the time they were completed. The location of the installations also sometimes proved unwise.

When existing buildings were used in Australia, X-ray departments had to be adapted to whatever space was assigned to them. This varied from building to building. The departmental layout had to conform to the area allotted, the amount of equipment available, and the anticipated workload.

When hospitals of the cantonment type were being built, radiologists had to adapt to or modify the basic plan for this type of building, as, for instance, the 42d General Hospital did at Highland Park near Brisbane. The materials in this building were gumwood, sheet composition, and asbestos siding, and the X-ray department was part of a general clinical building that also housed the surgical, dental, and otolaryngologic departments.

The facilities at the 12th Station Hospital in Townsville, Australia, represented a special type. Here the houses were built on pilings, for the sake of coolness, and most of them were connected by ramps added by the Army at the first floor level. When the ground level was floored with cement,

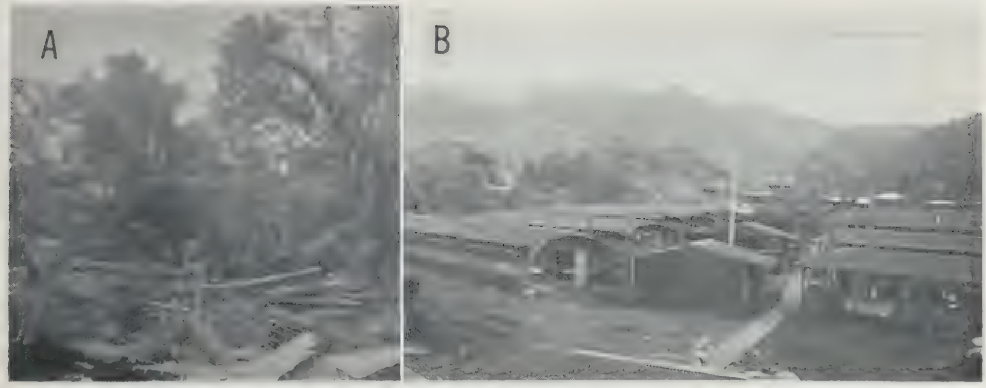

FIGURE 200.—Location of 125th Station Hospital, Milne Bay, New Guinea. A. Original site of hospital. Jungle growth had to be cleared before construction could proceed. B. General view of hospital.

each house, in addition to the ward on the first floor, had bathing, kitchen, and convalescent facilities below it.

NEW GUINEA

There were almost no buildings available on New Guinea that could be commandeered for hospital purposes. Large numbers of casualties were expected. The plan was to use prefabricated, demountable, portable structures, which would be easy to pack, ship, and assemble, and which would require only the barest essentials of construction. It was estimated that a minimum of 200, and a maximum of 400, such units would be required, and orders were placed in Sydney for a sufficient number to provide 28,250 beds.

Major Reavis was able to advise the U.S. Army Engineers and the civilian Australian engineers employed by the U.S. Army in the planning of the X-ray departments of these prefabricated hospitals. Each department was housed in a single building, 20 by 30 feet, with prefabricated walls in 10-foot sections. This would provide 600 square feet of floor space (fig. 203). One room was 20 by 15 feet, and adjacent to it was a darkroom, as well as a small office. The wall between the X-ray room and the darkroom and office was leaded up to 7 feet. Whenever feasible, the building was set on a concrete slab. The request for a toilet introduced no complications, since water was necessary in the darkroom.

The building just described was the basic unit. When a larger X-ray department was necessary, another room could be added, or two basic units could be erected together.

Hospitals in New Guinea, as later in the Philippines, did not have a very high priority. This meant that the sites on which they were located were not always satisfactory and that it was often difficult to obtain material and

FIGURE 201.—Buildings of 9th General Hospital, Biak, New Guinea.

labor. A number of hospital units constructed their own buildings with such lumber as was available and such help as they could secure from Army Engineers. In general, these buildings were better than either tents or native huts. When it is remembered that they were put up by personnel trained to operate and staff them rather than to build them, it is fair to say that an exceptionally good job was done by all concerned. It would have been more sensible, however, to have the buildings put up by qualified construction workers and bring in trained radiologic and other medical personnel only when they were ready for use.

At most hospitals in the field, furniture for the X-ray department was constructed from packing cases and similar material.

Since it was not possible to wait for the prefabricated buildings just described, hospitalization in the early New Guinea campaigns had to be provided by other and more primitive means. Tents were used very generally, but they did not hold up well; the canvas rotted and molded within 2 or 3 months. Native huts with roofs of kunai grass were somewhat more satisfactory, but there were a number of objections to them: Mites and other insects in them were a nuisance. Sawdust from wood borers made the occupants of the rooms below extremely uncomfortable. Most important, when the weather was dry, these huts were a fire hazard.

THE PHILIPPINES

After Manila was retaken, a few buildings were again available for hospital use, including a few hospitals. In general, however, hospital facilities in these islands were similar to those described for New Guinea.

When the first detachment of the 49th General Hospital moved to Leyte,

FIGURE 202.—Ward at 362d Station Hospital, New Guinea. Note mosquito nets over Army cots, corrugated tin roof, and concrete slab for flooring.

it occupied one of the few buildings standing in Tacloban (fig. 199), an industrial school, which was quite satisfactory for hospital, including radiologic purposes, except for the sea of mud with which it was constantly surrounded. Later, when the full complement of the hospital arrived, a completely new building was constructed in the middle of a rice paddy. Just as this building was completed, the hospital received orders to go to Manila. Here, after several days' delay, the building it was scheduled to occupy, the former De La Salle College, was finally captured. At the end of a week, it was concluded that it was not practical to convert it to hospital purposes, and the 49th General Hospital was moved to the large San Lazaro Race Track (fig. 199).

This proved an excellent arrangement. The interior of the building was divided into wards. The offices were used for the clinical laboratory, operating rooms, and X-ray department. Maj. (later Lt. Col.) Simon Pollack, MC, was in charge of the X-ray department and had it functioning even before it was structurally complete. During this period, films were read in the main hospital corridor.

CONCLUSIONS

Since construction of an X-ray section requires more time and care than any other hospital facility, because of the necessity for lightproofing the darkroom and for protection against radiation, the experience in the Southwest Pacific Area proved that it should be the first of all buildings of a hospital to be undertaken.

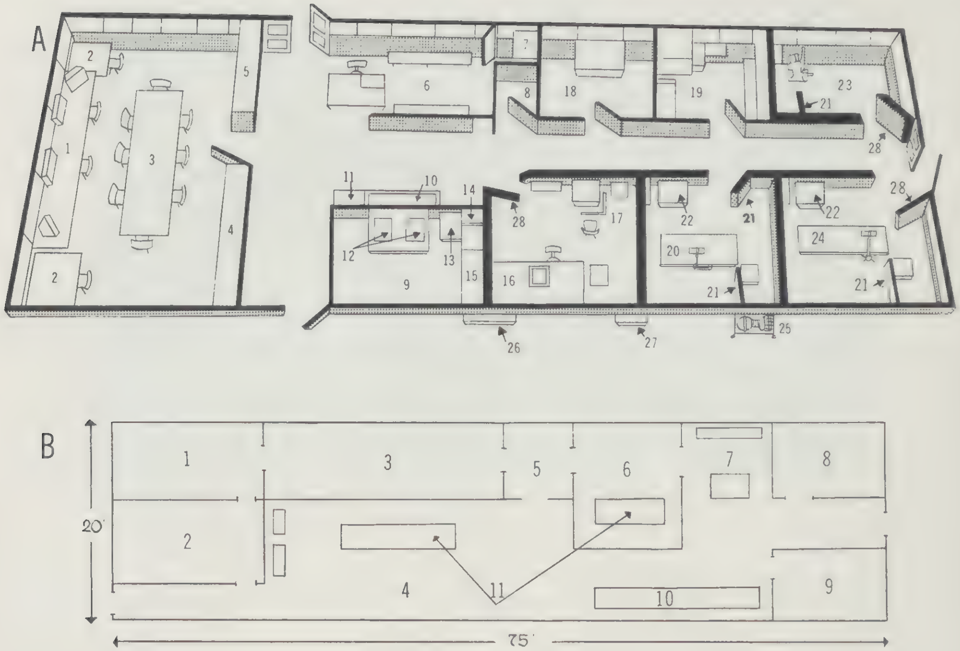

FIGURE 203.—Typical layouts of X-ray sections of general hospitals in New Guinea, 1944–45. A. Layout of X-ray section of 9th General Hospital, Biak, 1944. X-ray protection in this hospital was by sanded walls (p. 579): View boxes and reading desks (1), desks (2), conference table (3), medical library shelves (4), film file shelves (5), waiting room (6), linen closet (7), utility closet (8), darkroom (9), wash tank and view box (10), film drier (11), developer and hypo tanks (12), wet film pass box (13), cassette pass box (14), film loading bin (15), horizontal fluoroscope (16), vertical fluoroscope (17), maintenance shop (18), utility room (19), extremity X-ray (20), lead shields (21), lead-lined film boxes (22), chest X-ray (23), general X-ray (24), portable generator (25), darkroom ventilator maze (26), fluoroscopic ventilator (27), and lead-lined doors (28). B. Layout of X-ray section of 27th General Hospital, Hollandia, 1945: Reading room (1), office (2), darkroom (3), exposure room with X-ray table (4), dressing room (5), fluoroscopic room with table (6), fileroom and office (7), spineroom (8), supply room (9), bench (10), and table (11).

It was also found important to make provision for moving litters from wards to the X-ray section and for moving portable X-ray machines to the wards and operating rooms. In the cantonment type of hospital, this could be accomplished by grading the walks when it was not possible to pave them. It was completely impractical to try to roll either patients or equipment through muck and mire.

Since wartime hospital buildings are seldom permanent, and since hospitals in the Tropics were not nearly as substantial as those in temperate zones, Major Reavis suggested that it might be possible to employ a type of construction that would permit material for crating X-ray equipment to be used for prefabricated walls and other sections. The hospital walls could

thus be set up as the equipment was uncrated. If the utility section and darkroom were stamped out of one piece, a prefabricated X-ray department would be ready at once. The utility section, of course, should be lead-lined.

SPECIAL EXPERIENCES

The building experiences of one or two hospitals might be related. They are typical of how many hospitals in the Southwest Pacific Area not only practiced medicine but also helped to construct the facilities in which it was practiced.

4th General Hospital

When the 4th General Hospital moved from Melbourne to New Guinea early in 1945, it occupied an old Japanese airstrip, 2 miles north of Finschhafen. The airstrip was located on flat coral shelves, 50 to 75 ft. above sea level. The temperature in this area frequently reached 130° F., and the yearly rainfall was 186.5 inches. Extensive ditching operations were necessary for drainage.

The hospital consisted of prefabricated huts made in Australia, set on concrete slabs. Since the wards filled with patients as fast as they were opened, they had to be supplemented by tents, which were erected on the coral base, no lumber being available for floors. Hospital personnel were housed in pyramidal tents.

The 4th General Hospital left New Guinea on 23 July 1945 and arrived in Manila Bay on 18 August. It staged first at the Wack Wack Country Club on land that was once a well-kept golf course but that then was a poorly drained quagmire.

The hospital area proper was located 8 miles from Manila, in a flat, barren area of poorly drained rice paddies. The soil was sour, and when it was sodden and wet, as it was a large part of the time, it exuded the odor common to all soil in a region fertilized by generations of night soil. The hospital was constructed so close to the main road that dust was a constant annoyance, even in the wet season, and noise was almost equally annoying.

54th General Hospital

The 54th General Hospital arrived at Milne Bay in New Guinea on 24 March 1944, and its personnel were at once catapulted into the problems of jungle life in a coastal base said to have more rainfall than any other area in New Guinea. It rained for 50 consecutive days after the hospital arrived, and it was in these circumstances, modified by an occasional typhoon, that an area was cleared for hospital operation and tents were erected.

Eventually, a cantonment type of hospital was completed, constructed of the portable fabricated huts made in Australia. Jungle trails established by the natives and used by the Japanese had to be widened by carving away the dense red soil of the hillsides.

When the jungle undergrowth had been cleared out of the hospital area, a few of the tall, stately trees were left, for the sake of the shade they afforded, though it amounted to little more than a small spread of branches and leaves at the top. The ominous significance of these tufts of foliage and of the fan-shaped roots of the trees, which long ago had been weakened by erosion of the top soil, was not realized until one of the trees crashed to the ground, demolished a utility building, and caused the first death among hospital personnel. After this fatal accident, it was evident that even their light branches made these ancient trees topheavy and that, when they were no longer supported by jungle undergrowth, their shallow roots were likely to become loosened and that the trees would sway and fall when any winds blew. The Corps of Engineers was consulted, and on its advice the hospital area was completely cleared of trees.

CHAPTER XXX

Equipment and Operation

Charles W. Reavis, M.D.

BASIC EQUIPMENT

All general hospitals that operated in Australia during the early months of the war had at least one 200-ma. unit with tilt table and a few had double-tube units (fig. 204A). These hospitals also had urologic tables, and a number had several field units.

The general hospitals that went directly to New Guinea later in the war, and still later to the Philippines, brought five field units with them, three with field tables and two with mobile carts (figs. 204B and 204C). These hospitals usually had urologic units, which had to be energized by one of the field units.

A number of Air Forces installations used the Picker lightweight airflow unit, but the basic item of equipment in SWPA (Southwest Pacific Area) was the Picker Army field unit (p. 62). There were complaints from some radiologists and some technicians about certain features of this unit, but the general impression was that such deficiencies as it presented could be explained by environmental conditions and that, in spite of rough handling, heat, humidity, and rust, it stood up well throughout the war. It can fairly be said that this was the best X-ray unit ever produced, when it was used for the purposes for which it was intended.

DISTRIBUTION

One of the important phases of work done by Maj. Charles W. Reavis, MC, as Acting Consultant in Radiology, concerned the survey and distribution of equipment. As pointed out elsewhere, his reports, on file in The Historical Unit, U.S. Army Medical Service, Walter Reed Army Medical Center (p. xxi), provided an inventory of the equipment in SWPA and its precise location.

In many respects, the initial distribution of X-ray equipment was inequitable. Some small units had more than they needed; the volume of work in a number of them did not warrant the operation of a second machine. Some large general hospitals had only field units. The 27th General Hospital, for instance, which examined 6,090 patients during the last quarter of

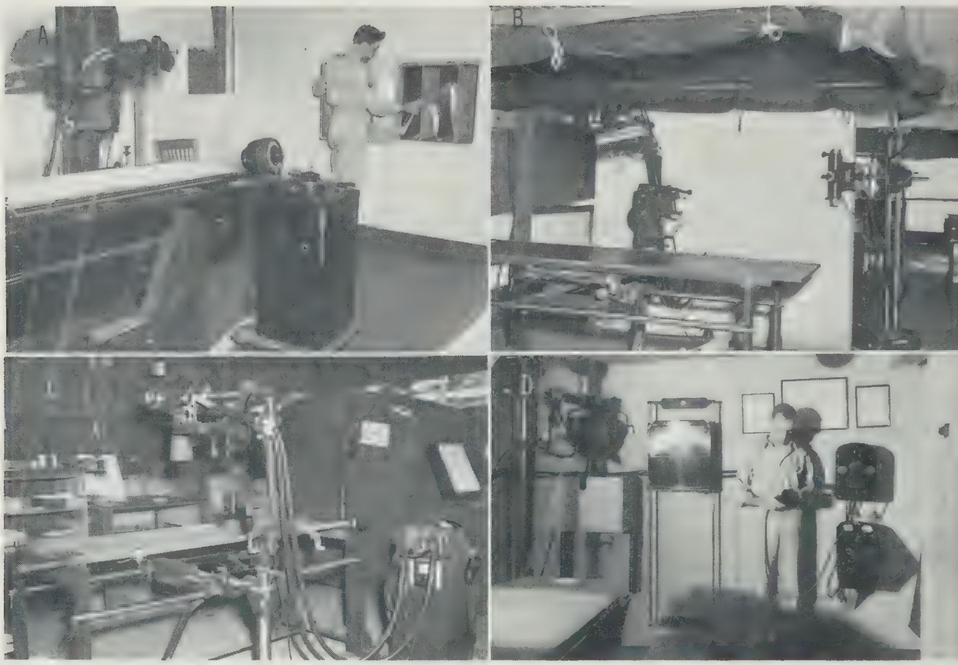

FIGURE 204.—Types of X-ray equipment used in Southwest Pacific Area. A. General Electric single-tube radiographic-fluoroscopic 200-ma. unit, with General Electric 39 table, surgical clinic, 118th General Hospital, Sydney, Australia, March 1944. Note opening in wall that connects with darkroom and serves as pass box. B. Army field unit set up on right as portable equipment and on left with field table, 31st Station Hospital, New Caledonia, May 1945. C. Stationary Army field unit, with table and standard Army litter used as tabletop, 5th Field Hospital, Lae, New Guinea, February 1944. D. Small portable unit set up as permanent installation on hospital ship *Maetsuycker*, Newstead Wharf, Brisbane, Australia, July 1944.

1944, maintained, with reason, that it could do much better work if it had at least one 200-ma. machine instead of the 30-ma. field units with which it was operating. A number of station hospitals had X-ray machines in storage. One of these machines in the Townsville base, Australia, was immediately issued to a general hospital in which it was badly needed. In one installation, Major Reavis found extra equipment being installed by a technician, though no radiologist was assigned to the hospital and its present equipment was entirely adequate for the workload possible under the circumstances.

In the middle of 1944, Major Reavis reported, there were in SWPA the following items of X-ray equipment: Ten 200-ma. units, two 100-ma. units, and a Stanford tilt table that had been purchased in Sydney and that was energized by a field unit generator. At the same time, the medical supply depot in Milne Bay, which was the main supply depot for the advanced and intermediate sections, had as replacements or surplus 47 transformers; 82

tubes; 43 controls; 24 chassis chests; and six 5-kw. 60-cycle electrical generators. Major Reavis promptly arranged for the distribution of much of this equipment to hospitals in which he had observed the need for it. The 4th Air Force Depot, which was handling a large amount of dental work, requested a dental unit; none was available, but it was supplied with a field unit.

The X-ray section of one general hospital in New Guinea had an elaborate setup, including a 200-ma. machine, which the technicians had installed; a cystoscopic table; two complete field units; two additional mobile units; a Sweet localizer; and a complete darkroom, with 10- and 15-gallon tank inserts. The section had, however, only a limited supply of accessories. It had few screens, and no 8- by 10-inch cassettes. These were provided. A number of units had neither portable grids nor Bucky diaphragms, though they had been requisitioned. It was arranged to supply them as rapidly as they became available to any department that lacked them.

The 80th General Hospital, in its first quarterly report for 1945, complained that no heavy-duty equipment had been received in spite of numerous requisitions for it. Later, the Chief of Staff of the Philippine Army, who was the former Medical Director of the Quezon Institute, arranged to give the hospital a 500-ma. General Electric machine salvaged from the Japanese occupation.

Special Instances

Perhaps the simplest way to describe the rather confused situation in respect to basic equipment in SWPA is to summarize the reports of a number of hospitals:

1st Evacuation Hospital.—The field-type equipment which this hospital possessed was first set up in the Brisbane area. The table was used horizontally and, after certain improvisations, in the upright position also. The foreign body localizing equipment was never unpacked. A more or less movable Bucky diaphragm was constructed from the grid supplied. In New Guinea, the Lysholm grid was again used, this time fitted onto a movable apparatus. Radiographs were good, the commanding officer implied in his report, more because the technicians were competent than because of the inherent qualities of the apparatus.

18th Station Hospital.—This hospital possessed the standard field unit but found that a tabletop constructed from an old refrigerator case was more satisfactory than a stretcher, which did not provide sufficient immobilization. The 14- by 17-inch Libell-Florsheim grid provided was of extremely poor quality; its lines were coarse, and they were objectionably apparent on the radiograph. Cones were in short supply, but good results were obtained by the use of diaphragms of different sizes. Films of better quality were obtained when the coning technique was used.

The Army field unit at this hospital was used chiefly for the diagnosis of conditions that could be treated on an outpatient basis. Patients who required gastrointestinal series and barium enemas were sent to nearby hospitals, usually the 42d General Hospital.

12th Station Hospital.—The Picker field unit stood up well in this hospital. The fluoroscopic table was regarded as usable but not really adequate. The staff were among the numerous radiologic personnel who looked with great disfavor upon the foreign body localization apparatus. The comments on it were similar to those made by personnel in

the European theater (p. 466). It was regarded as much too complicated for fieldwork and was generally thought, in fact, to have been devised by someone without field experience. Personnel of this hospital commented that it was unfortunate that the World War I work of Case (p. 53) seemed to have been forgotten.

361st Station Hospital.—This hospital gained considerable experience with its original Army field unit during the almost 3 years in which it progressed from Australia to the Philippines. A second unit, received at the end of 2½ years, arrived in its original crates. The main contact in the very depth of the control panel, was out of adjustment, but department technicians were able to repair it after a long day's work. The equipment was in active operation about 90 percent of the time and was regarded as entirely satisfactory.

35th General Hospital.—This hospital considered the Picker field unit a good piece of equipment for temperate and cold climates but would have preferred, for the tropical climate of SWPA, a self-contained transformer tube type of machine, sealed in one head, such as was used in one hospital ship in the area (fig. 204D).

42d General Hospital.—This hospital, which was in SWPA from 1942 until the end of the war, had two field units and a 200-ma. table in its original equipment. It was soon able to acquire a 500-ma. generator and control from Watson Victor, Ltd., in Brisbane, a subsidiary of General Electric of England. By 1 January 1943, the generator was installed over a General Electric 39 table, part of the original hospital equipment, which had been salvaged from the wreck of the SS *Rufus King* (p. 628) and repaired by Watson Victor, Ltd. (fig. 205). The Young urologic table was operated from the same generator. A throwover switch was used for the high-tension circuit. A rotating anode tube that was requisitioned was never received.

After the 42d General Hospital moved to Highland Park, Brisbane, it obtained a double-tube, tilt-table, 200-ma. unit. With this added equipment, it could operate two complete fluoroscopic rooms.[1]

105th General Hospital.—The original field equipment of the 105th General Hospital consisted of three portable units, two of which were soon requisitioned for field hospitals. The single remaining unit was sufficient to take care of the work in the operating room and wards, handle routine work, and act as an energizer when the Young table was used for pyelograms. This hospital also had two 200-ma. tables (Picker Century Units), which were used for gastrointestinal studies; a localization table, which was used routinely as an additional table; and dental equipment.

FLUOROSCOPY

Fluoroscopic examination was difficult because the field equipment was cumbersome. When it was used in the vertical position, up-and-down travel was so limited that the patient, during a gastrointestinal examination, had either to stand on a box or to squat. In either event, the radiologist's mind was more likely to be on the mechanics of the examination than on his patient. Fluoroscopy in the horizontal position, which was usually carried out with the patient on a litter, was fairly satisfactory as long as the subject was thin.

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[1] At the 42d General Hospital, when a wheelchair that was part of the original equipment was uncrated, there was found, in the same crate, a glass bowl eye-localizing apparatus. No one knew how to use it, and there was no tube in the hospital that would fit it, which was understandable: The newspapers in which it was wrapped were dated 1918. A modern Sweet localizer was purchased from Watson Victor, Ltd., and was soon used routinely. Foreign bodies in the eye were frequently encountered at this hospital, it being one of the few units in SWPA that had both radiologists trained in the Sweet technique and ophthalmologists capable of handling intraocular foreign bodies.

FIGURE 205.—Control cabinet, part of 200-ma. General Electric X-ray equipment, salvaged from the SS *Rufus King* after it sank in the harbor at Brisbane. The equipment shown, intended for use at the 42d General Hospital, could not be put into operating condition, and another control stand and generator had to be obtained.

As noted elsewhere, fluoroscopy was frequently done at night because to carry it out during the daytime required the complete elimination of ventilation. At night, it could be performed with the sides of the tent up, or in the open.

IMPROVISATIONS

While the Army field unit proved fundamentally satisfactory in SWPA, the accessories supplied with it—which were sometimes not supplied—left much to be desired in a number of respects: Radiologists and technicians made up for many of these deficiencies by clever improvisations, as follows:

1. Practically all hospitals improvised some kind of chest board.

2. Many hospitals made sinus and mastoid boards out of plywood and sheet lead.

3. Shell casings made very good cones (fig. 206), which were frequently not provided.

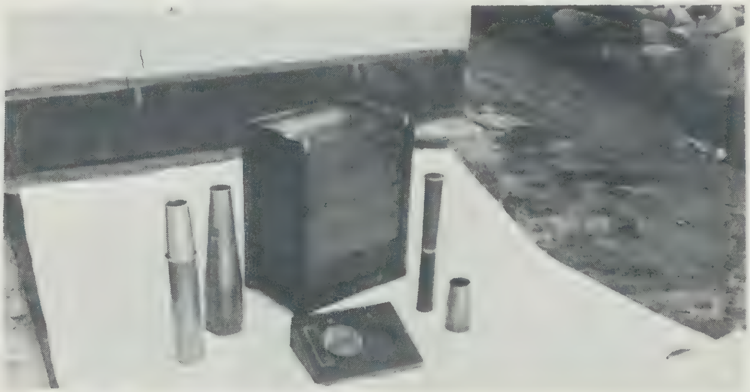

FIGURE 206.—Improvised cones, mastoid board, and developing tank made from scrap lumber from packing cases, 9th General Hospital, Goodenough Island, 1944.

4. More accurate timing for exposures of the chest was obtained by using the timer of the Bucky unit, which was set on $\frac{1}{10}$ second, rather than the standard timer.

5. Adding tracks to the mobile field unit made it possible to maintain it at a constant distance from, and parallel to, the examining table, and at right angles to the cassette changer.

6. A number of departments made serialograms by cutting out a corner of the sheet lead, or made a tunnel with a sheet lead top, with a hole in the middle of the top, to permit four exposures on a 10- by 12-inch film. This method added to the speed of the exposure and reduced scattered radiation. Maj. Morton Helper, MC, who used the factors 85 kilovolt peak, 10 milliampere second, 28-inch target film distance with screens and no grid, emphasized that when serialograms were being made with a central aperture, the position of the patient was all-important. His method was to position the patient under the fluoroscope and use a skin marking pencil with a small piece of lead in the tip.

Maj. Joseph L. Morton, MC, also devised a method of getting a compression cone and four spot films on an 8- by 10-inch film, using the field unit. He directed his technician to switch from fluoroscopy to radiography by a single toggle on the control panel. His findings were recorded exactly as if he had been using conventional equipment. Some time after he had adopted this technique, a medical inspector from the 105th General Hospital brought

him a message from the gastroenterologist there that the spot film work at the 12th Station Hospital was so satisfactory that not a single one of the diagnoses of peptic ulcer had been reversed in patients evacuated to the rear.

7. Major Helper also made barium sulfate more palatable by mixing it with the synthetic beverage powder and the sugar in the C or K rations.

8. The field unit had no tabletop, and the use of litters, for which provi-

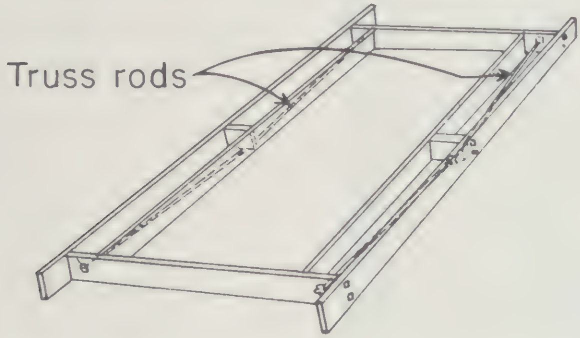

FIGURE 207.—Frame devised to fit X-ray field table unit with pressed wood cover removed.

sion was made, was frequently unsatisfactory, for obvious reasons. Some hospitals made fixed tops out of 3-mm. aluminum, supported by steel rods. Others made tops of pressed wood (fig. 207), using metal trusses to control the tendency to sagging.

9. Vertical fluoroscopy with the Army field unit was awkward, cumbersome, and very tiring when many chest and gastric examinations had to be made. By the mechanism provided, the tube screen assembly was swung out and rotated to the vertical plane, and up-and-down motion was provided by a crank. Lt. Col. Dan Tucker, MC, and Capt. (later Maj.) Arthur J. Tillinghast, MC, at the 9th General Hospital, improvised a more satisfactory vertical fluoroscope by standing the Army table unit on end and fixing it to the floor with lag screws (fig. 208). The carriage was counterbalanced by using salvaged cable and pulleys from an airplane. The counterweights were made of sheet metal filled with sand. Because of outward thrust of the tube-screen assembly in the upright position, it was necessary to change one of the ball-bearing runner wheels from the front (top) to the back (bottom) of the track piping; this was done by bending a piece of scrap steel into a U and bolting it to the assembly frame. An axle for the wheel was made by running a bolt through the U at the proper distance. As a further precaution against forward thrust, the arm that carried the grooved wheel on the back (bottom) pipe was lengthened with a piece of scrap iron and the wheel was placed behind the pipe. Other hospitals used variations of this improvisation.

10. At the 227th Station Hospital, Major Morton found it impossible to

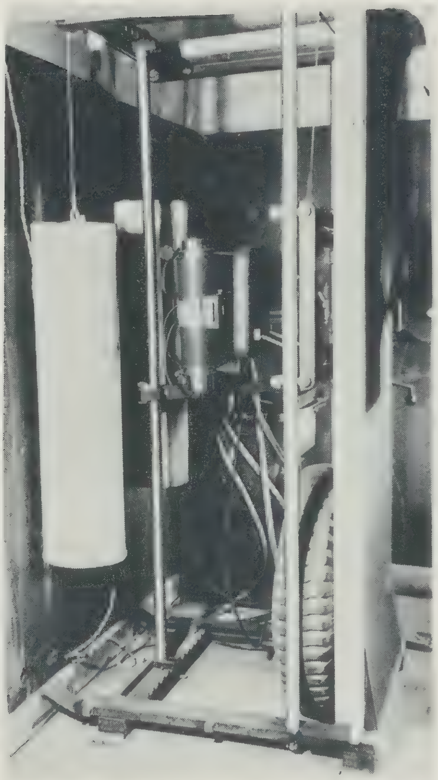

FIGURE 208.—Improvised equipment for vertical fluoroscopy, using airplane cables and pulleys, sand in a galvanized cylinder, and a tire for a bumper, 9th General Hospital, Biak, New Guinea, 1944.

examine a patient in a body cast, who could not be moved, without mirrors available to solve the problem in depth. He therefore set up stereoscopic films, and, using the old trick of crossing and uncrossing his eyes, found it possible to achieve stereoscopic perception.

11. Fine detail was provided by the conversion of a 75-mm. brass cartridge case to a long cone. The small end of the shell casing was adapted to fit into the X-ray cone slot, and the large end, when cut off, provided a spot 5–6 inches without penumbra and quite sharp. This technique was particularly useful when additional vertebral detail was needed.[2]

12. The cassette changer provided for in tables of equipment never reached the 42d General Hospital, and one was therefore improvised. Two pieces of soil pipe and two old drums secured from the Corps of Engineers were used to construct a vertical stand, across which two angle irons were placed. Part of a sheet of Bakelite was leaded, and with this apparatus a spring method of shifting cassettes was achieved.

13. The 42d General Hospital had no stereoscope, but mirrors purchased from F. W. Woolworth & Co., Ltd., of Australia were set on pins in a box and raised, lowered, or otherwise varied in position to create the angle desired.

[2] Actually, the use of a cone does not increase or improve detail. It simply restricts secondary radiation, which obscures detail, and thus makes detail more visible.—K. D. A. A.

When two view boxes were set on a shelf, very satisfactory stereoscopic vision was obtained. This technique was used most often to study skulls and chests. It was also useful for localizing foreign bodies.

14. When the 120th General Hospital was located in the Santo Tomas University buildings, it had five Picker field units. Through friends in an engineering company, aided by the judicious use of alcohol as a medium of exchange, the radiologist, Maj. Richard O. Gale, MC, was able to procure enough ¾-inch plywood to make stationary tables for four of them. He also put to use an old, prewar General Electric 200-ma. machine with motor-driven table, which had been owned by the University and stored during the occupation. The under table tube was set up for fluoroscopy with salvaged cables. The Bucky diaphragm was hand-operated and the mobile unit moved in position over the table.

15. An attempt to construct a planograph at the 42d General Hospital was not very successful. A metal strip was attached to the head of the tube and a fulcrum was selected. No mechanical means of movement was provided, but during the exposure, a technician, wearing a lead apron, shifted the tube stand and rotated the tube at the same time, so that the tube and the Bucky diaphragm moved concurrently in opposite directions. Maintaining the arc of rotation of the tube proved extremely difficult and unreliable, and the problem was never solved. The apparatus was therefore not put into full operation, since none of the laminographs made with it were entirely satisfactory. Perhaps, if patients had been encountered who needed such studies, the idea would have been pursued further.

16. Major Helper devised a tube-angle meter that directed the central ray accurately at various angles to the horizontal plane: A circle cut from paper and ruled in angles was mounted on a stiff piece of cardboard and attached in a vertical plane to the tube head. A free-swinging pointer, weighted at one end, with its axis in the center of the circle, indicated the true position with respect to the horizontal plane.

17. An immobilization device, also the idea of Major Helper, consisted of a cloth band, weighted at each end by sandbags and long enough to hand over the sides of the table. This band could also be used to immobilize patients for upright radiography by using hooks on either side of the chest boards to draw the bands securely by means of gravity.

18. At the 42d General Hospital, a very satisfactory kymography grid was made of strips of lead, separated by strips of cardboard and enclosed in sheets of aluminum. The Bucky grid was removed and the improvised grid substituted for it.

19. Also at the 42d General Hospital, a satisfactory reading desk was constructed from a mess table and salvaged boards (fig. 209).

20. At the 9th General Hospital on Goodenough Island, improvisation permitted spinal and other examinations that required the use of the Bucky diaphragm (fig. 210).

FIGURE 209.—Maj. (later Lt. Col.) Herbert D. Hebel, MC, at improvised reading desk, 42d General Hospital, Highland Park, Brisbane, Australia, 1943. The desk was made from an Army mess table, on top of which two uprights were placed. A curved section of board supplied the shelving for three view boxes, with hot lights. The dictaphone occupied a fourth section. When a clean desk top was desired, the entire assembly could be pushed back along the uprights.

OPERATIONAL DIFFICULTIES

Climatic Conditions

All apparatus in SWPA had hard usage. It was not always employed efficiently because personnel operating it were not always properly trained and frequently had had little experience. For a considerable part of the war, it was not adequately maintained and serviced (p. 625). Inadequate stabilization of current was another important factor in its deterioration (p. 616). With due respect to all of these considerations, however, deterioration and ultimate failure of equipment in SWPA could be explained chiefly by environmental factors of climate, humidity, and heat (fig. 211).

Major Reavis suggested that when units were staging for long periods of time, some arrangement be made for last-minute delivery of the X-ray equipment, since it deteriorated rapidly on exposure to the damp, humid climate of SWPA.

Major equipment.—It was only a short time before the X-ray units in this tropical climate became covered with mold and rust. The 17th Station Hospital personnel could not inspect their equipment for the 2-week period it was in transit between Australia and Milne Bay. When it arrived, there were considerable amounts of mold around all the connections. Thereafter, the tech-

FIGURE 210.—Improvised equipment for horizontal radiography requiring the use of a Bucky diaphragm, 9th General Hospital, Goodenough Island, 1944. The only Bucky diaphragm supplied was underneath the cystoscopic table. It could be used for spinal and other examinations when a second table was placed at the end of the table equipped with it.

nicians adopted the plan of running the machine for a short period every day simply to keep mold from forming. Rusting was frequent but could be kept to a minimum by daily cleaning and oiling of all parts of the equipment.

In Milne Bay, ants got into the X-ray machines and regular checks had to be made to clean them out.

Some hospitals reported good service with their original tubes through the entire period of their operation, but it was necessary, as a rule, to replace the tubes more often than in a temperate climate. A department which had only a single field unit sometimes had to close for the 4 or 5 days necessary to obtain new tubes. Medical Supply periodically asked for lists of tubes on hand, in order to requisition additional tubes from the Zone of Interior, so that replacement would be promptly available.

FIGURE 211.—Capt. Ralph C. Moore, MC, adjusting the air conditioning, 105th General Hospital, Gatton, Australia, January 1943. January is one of the hottest months in Australia.

Cables.—The major difficulties were with the cables. Moisture got into the terminals and apparently condensed there. As a result, the current would arc, and the increased load burned out the cables. Maj. William C. Coles, MC, reported that when the 361st Station Hospital was on the island of Noemfoor, Netherlands New Guinea, just south of the Equator, where the average humidity was 97 percent, electrical arcing resulted in scoring of the cable terminals and receptacles in the transformer and the tube. Scraping of the burned areas was necessary but could be handled within the hospital. Operation was maintained by revarnishing these areas and baking them in sunlight or by the heat generated by multiple light bulbs. A light bulb cradle, of the kind used for burned patients, was sometimes employed for this purpose. If cable terminals and receptacles were dried by one or another of these methods before the equipment was reassembled after a move, the frequency of electrical arcing was decreased, and the unit could be used for diagnostic purpose. Superficial X-ray therapy at 100 kv. and 4 ma. was not practical because, with the machine at this setting, arcing occurred in about 30 seconds.

At the 35th General Hospital, Lt. Col. Horace D. Gray, MC, reported that the small generator supplied with field units proved entirely inadequate for the type of X-ray work required in a general hospital. An attempt was made to use one of the larger generators that supplied power to the entire hospital area. The source of power was adequate and the generators operated continuously, but the one nearest to the X-ray department was more than 400 feet away, and the necessary wire to link it to the department was not available on the base. Signal Corps telephone wire, which was used as a substitute, acted more as a resistor than as a conductor. The technicians were able to

produce films of fair quality by anticipating the drop in voltage when the high-tension circuits were closed.

Cables began to break down around 70 kv., and any operation above 85 kv. was almost impossible. In some hospitals, before work was started each morning, the cables were removed, cleaned with carbon tetrachloride, and regreased with petrolatum. Friction tape was then put around the cuffs of the cables in an attempt to seal out moisture.

Even with these precautions, the radiologist reported, there was scarcely a day when there was not a cable failure at the 35th General Hospital. Fortunately, the department had six field units, and by taking cables from machines not in use and requisitioning additional cables in advance of the need, it was possible to keep at least one machine in operation at all times.

Hospitals operating with only one field unit each were not so fortunate early in the war, when replacements were slow. The 18th Station Hospital, for instance, once had to wait 3 weeks for a replacement, and it was only by good luck that no pressing radiographic problems arose during this period. Early in the war, it was sometimes necessary to move patients from one hospital to another for examination because there was no replacement for burnt-out cables. Later, when a repair department was set up with adequately trained personnel, this expedient was no longer necessary.

An occasional radiologist explained the blowing out of high voltage cables by defects in manufacture or as the result of faulty packing and exposure in transit. There was general agreement that length of operation and intensity of use did not play a particularly important part. Most observers believed that heat and humidity were chiefly responsible for breakdowns and also believed that their effect could be minimized by baking the tube housing and cable, using lubricants plentifully, and assembling the unit while it was still hot.

Cassettes and screens.—Cassettes were generally of standard size (8-, 10-, and 12-inch), but an occasional X-ray section had such odd sizes as 11- by 14-inch or 12- by 15-inch. Since films were not issued in corresponding sizes, Major Reavis recommended that films be cut to these sizes or that the screens be cut and used in cassettes of conventional size. Cassette holders for chest examinations and for polygraphic examinations of the stomach were all improvised.

The usual plan of keeping cassettes loaded for immediate use proved entirely impractical in northern Australia, New Guinea, and the Philippines. They had to be loaded immediately before exposure. Otherwise, because of the intense humidity, the emulsion from the films stuck to them and hastened their deterioration. The cassettes were often rusty when they were received, and therefore had lost their spring and were difficult to open and lock. Many of them had light leaks, and contacts were poor because of warping.

Intensifying screens deteriorated beyond use in 6 months or less, though later it was found that if they were stored in heated cabinets when they were not in use, growth of mold and fungi was retarded. Crystallization of the emulsion following blistering of the calcium tungstate in it and peeling of the

resulting blisters sometimes produced artifacts that made any finished film beyond interpretation, regardless of its size, though for some reason this chain of events was particularly likely to occur in the 14- by 17-inch films used for chest radiography.

Developer stains were frequent because the technicians were obliged to work in hot darkrooms and were likely to be careless in their haste to get out of them. Even with the best of care, the usefulness of screens was limited, and in a number of units, they were discarded and the cassettes were used as film holders. Radiologists soon learned to ignore such imperfections as specks and artifacts in interpreting radiographs.

Replacement of screens was slow and unsatisfactory, and Major Reavis warned the Medical Supply Division that they should be requisitioned from the Zone of Interior well in advance of their need. He also recommended to all installations that they use paper folders exclusively on extremity examinations.

Accessory equipment.—Accessory equipment deteriorated as rapidly as basic equipment. Measuring calipers promptly became rusty, no matter how carefully they were protected. Darkroom timers quickly became affected by the high humidity. View boxes rusted out and replacement fluoroscopic bulbs were in very short supply.

Film hangers rusted and tended to break apart at points of welding. X-ray departments located near ordnance depots or quartermaster facilities could get them repaired. Since, however, hangers were in short supply and requisitions for them were frequently not filled, those available were often reserved for the actual processing of the films, which were then hung on lines to dry, usually suspended by paper clips through the corners. Plastic rulers held up satisfactorily under climatic conditions but were readily misplaced.

Fungus and mold were hard on leather and rubber goods, and on fabric-covered articles. Lead aprons and gloves therefore deteriorated rapidly. The supply of dark adaptation goggles was sufficient, and they held up very well.

Current

The source of electrical current furnished an individual problem for each hospital X-ray department. The difficulties began in Australia. There, whenever possible, hospital units were located in existing buildings that had power and equipment that could be converted to hospital use. Local current, which was 220 volts and 50 cycles, had to be stepped down for use by U.S. Army equipment. When the 42d General Hospital occupied Stuartholme, in Brisbane, adequate wiring was installed and 110 volts were pulled from both sides of the 220-volt line. The 50-cycle current was thought by some radiologists and technicians to be detrimental to the X-ray equipment, but, in spite of this real possibility, the use of local power was of great value and was preferred to other methods.

Some U.S. hospitals used the Australian Southern Cross generator, which gave unstable results because it had a 50-cycle rather than a 60-cycle current. Tubes did not hold up very well under the circumstances. The six 5-kw., 60-cycle generators and twelve 10-kw. generators that Major Reavis located in the supply depot at Milne Bay were distributed as he recommended to hospitals having particular difficulties with their supply of current.

When the 18th General Hospital was operating at Charters Towers in Australia, there was no community or central hospital source of power, and the X-ray department had to generate its own electricity. This was done with a 2.5-kw. generator. When the generator was being set up for operation, it was found that a broken casting had allowed all the oil to leak out. After repairs had been made at a nearby airbase, the electricity proved ample for the field unit and the films produced were of very good quality.

Col. Vernon L. Bolton, MC, radiologist with the 1st Evacuation Hospital, reported obtaining excellent results by limiting the kilowattage to 85 and using from 20 to 25 ma. since it was seldom possible to get 30 ma. out of the unit from the available sources of community power. This hospital had its own source of gasoline generator power from the 110-volt generator. Many other hospitals were similarly equipped.

The greatest single difficulty in operation of X-ray departments in the field was failure to secure a consistent line voltage. The small gasoline generator supplied with the field unit was not adequate for a hospital doing a considerable volume of work. It broke down frequently, and the almost constant surge made the taking of X-rays difficult. Departments were well advised to keep at least one extra generator on hand to use in an emergency. The output of the generator was limited when the temperature rose above 100° F., as it frequently did. Standard exposure factors could not be used because of the frequent drop in milliamperes resulting from the fluctuation of the incoming current. Both time and films were wasted in the retakes frequently necessary.

Although the use of multiple generators was not usually regarded as satisfactory, the 9th General Hospital reported admirable results by operating two of their four 30-kw. Diesel generators at a time.

Capt. Ralph C. Moore, MC, reported that at the 105th General Hospital a relatively constant electrical supply was provided to the diagnostic room by stepping down the 415-volt transmission incoming line to 220 volts for a capacity of 60 amperes. This line supplied the two large X-ray machines when they were operating at peakloads with a drop of only 2 or 3 volts, which was within practical limits. The 110-volt circuits to the department which came off another line were much less constant; at peakload, they fluctuated up to 10 volts, which was too great a variation to permit use of the portable unit for radiation therapy.

The obvious solution of these difficulties, supplying X-ray departments with current by use of main hospital generators, was not always as satisfactory as it seemed on the surface because the variations of voltage made it difficult

or impossible to standardize technique. The difficulty could best be obviated by running a second powerline to the X-ray building, and it was recommended that this be standard procedure in all general and station hospitals.

The third quarterly report for 1945 of the 4th General Hospital, then in the Philippines, mentioned another difficulty: Wiring inserted through holes in metal supports was subject to the vibration caused by walking on light wood floors, with a resulting loss of insulation and frequent short circuits. The wiring, in fact, was too light to carry anything more than a few light bulbs. The sockets were also of a very cheap type, with exposed contacts. It was necessary to do an almost total rewiring job before this X-ray department could begin to operate.

All departments were advised, when an X-ray unit first became operational, to run it for 5 to 10 minutes at low kilovoltage and low milliamperage before throwing high loads through the high-tension circuit.

DARKROOM FACILITIES AND EQUIPMENT

The properly setup darkroom was entered by a maze. It was equipped with an Army field unit tank, a refrigerating unit, and a cassette bin and drier. Except in fixed hospitals—and not always in them—the ideal was seldom approached, and the darkroom furnished a constant problem in every X-ray department. In the hot and humid climate, it became intolerably hot, from the combination of elevated temperature and high humidity; ventilation was almost impossible to maintain, particularly when, to secure a lightproof room, it was necessary to set up a darkroom tent inside another tent or, occasionally, inside a building. In some locations, incidentally, it was necessary to check the darkroom daily for light leaks. At the 35th General Hospital at Milne Bay, for instance, small earthquakes almost every day opened up cracks in the walls, which here were made of asbestos siding. The cracks were repaired with roofing tar.

Quite aside from the comfort of the technicians, complete circulation of air and relatively normal humidity were essential for satisfactory processing of films. Abnormally high temperatures and humidity threw an additional load on the equipment and made the technicians so anxious to get out of the room that their work became sloppy. In most units, the standard rules for time-temperature processing were followed, but in many instances, the films were overexposed and then developed at a high temperature. This procedure shortened the processing period and also shortened the time technicians had to stay in the darkroom.

Condensation of moisture from the high humidity caused oxidation and corrosion of the electrical switches, the contactors, and the motors themselves. Films developed at high temperatures showed reticulation and clouding, which could be prevented by the addition of an extra hypo bath. Major Coles reported, at the 361st Station Hospital, that because of the high darkroom temperatures, the motor for the water pump on the film processing tank

burned out frequently, and repeated rewinding of the armature was necessary. This fault was later corrected by the manufacturer, who used a transformer to reduce the operating voltage of the water pump from 110 to 12 volts.

In some departments, the motor used to run the water circulating pump burned out so often that films were processed at temperatures up to 120° F., which meant that chemical fogging was superimposed on the heat fogging that occurred even on films put up in waterproofed packages.

In Australia, when the Southern Cross generator was used to provide current (50 cycle) for X-ray departments, many radiologists complained that the refrigerating motor of the compressor unit burned out rapidly.

The motor relay contact points and the moving parts of the processing unit were found to be insufficiently protected from the splashing of solutions. As a result, rust formed promptly, and excessive corrosion resulted in frequent short circuiting. The Office of The Surgeon General recommended that the capacity of the motor of processing units should be increased by a third and that splash baffles should be added between the processing unit and the developing tank to protect the refrigerating mechanism.

The small ventilating fan provided for the darkroom tent proved totally inadequate, and numerous improvisations were employed in its stead. At the 12th Station Hospital, dull black baffles excluded light but admitted air. Additional electric fans provided some help, but not very much. Some departments hooked up electric fans in front of lightproof vents. Some used the intake ducts from airplanes to bring air.

At the 105th General Hospital, a large fan salvaged from a wrecked tank was used to blow air in, and small fans were placed on the ceiling to blow it out. Maj. Ernest B. Newman, MC, reported that when the 17th Station Hospital was located in the Australian bush, the darkroom was ventilated by the standard method of blowing an electric fan over cracked ice. In New Guinea, where the electrical supply was inadequate, ventilation was secured by placing two electric fans in a compartment just outside the X-ray room and improvised from the air-intake, while a third fan circulated it inside the room.

Placing the cooling units for the developing tanks outside the building reduced the deterioration of the equipment from moisture in the darkroom. Satisfactory temperature control for the solution could sometimes be maintained if the tanks were placed adjacent to the darkroom and covered with a thatch shelter. Most departments kept their emergency generators outside the darkroom.

Not all department darkrooms suffered the structural complications reported by Captain Moore from the 105th General Hospital. The passbox opening was so large that films, patients, and technicians could all have passed through it at the same time with no crowding. The room was constructed with elaborate 2½ foot-wide doors, but the film bin and drier combination, which had to get into the room through them, measured 5 feet 4 inches by 3 feet.

Eventually, the wall was broken down and the darkroom rebuilt around the equipment. The tank was designed with a water depth of 10 inches, although the largest films to be developed in it measured 17 inches. Also, the original design provided for the water to run over the sides of the tank onto the floor rather than pass out through a drain. These and other structural errors were eventually corrected.

FILMS

Supply

The main source of film supply in SWPA was the Zone of Interior, though some purchases were made locally from the Australians. There were occasional shortages in certain parts of the area, but as a rule, the supply was entirely adequate. The only acute shortage occurred in the summer of 1943.

At one time when films were in short supply, preliminary chest examinations had to be made at the 42d General Hospital on all men admitted to an officers' training school in Brisbane. Fluoroscopy was substituted for radiography, 400 to 500 examinations being made in a single day (usually, for the convenience of both hospital and school, on a Sunday morning).

Condition on Delivery

While the overall supply was never a major difficulty, the state in which the films were received was frequently a very serious problem. Many were received in such condition that they were useless. Sometimes as much as 40 percent of a single lot had to be discarded, and occasionally the losses, from a combination of aging and other factors, reached 100 percent. Outdating was frequently due to the fact that hospitals were several months in transit and staging before their X-ray departments became operational. In a great many instances, however, the loss of films was caused by chemical fogging due to poor packing, unnecessary exposure to sunlight and moisture, and storage at excessively high temperatures. At Melbourne and elsewhere, films were sometimes left on docks, covered with tarpaulins, for days and even weeks. Fortunately, many of the films thus treated were still usable with special precautions (½ to 1 gamma of photographic density from fog). Contrast was high because of the high temperature of the developing solution.

A number of hospitals found it wise to develop one film from each pack as soon as a lot of films was received. The developed film was placed on the outside of the pack, and the films which showed the least damage were used.

Late in the war, the policy was adopted of shipping films to SWPA by refrigerated ships, and it is unfortunate that this could not have been done sooner. Major Reavis believed that the best way to transport films was by air, and he made this recommendation verbally to the Chief of the Professional Service Division, Office of the Surgeon, SWPA, and to the medical

supply officer. He also recommended that supplies of films from the United States, even when tropically packed, should be kept on the Australian Mainland, preferably in the Brisbane or Sydney areas, and shipped by air to New Guinea bases only as they were needed. It was essential that adequate supplies be kept on hand in advance bases, but enough losses would occur through simple aging without inviting more by storing large quantities in the hot, humid climate of New Guinea, as was then being done.

For some reason, 14- by 17-inch films seemed more prone to heat fog than films of other sizes. This was true even when they were tropically packed (that is, in metal containers) as most films were packed late in the war; heat and humidity seemed to affect them regardless of how they were put up.

When the films were finally shipped and stored under refrigeration, a label attached to the package warned that they should not be used until they had reached room temperature, to prevent condensation, which would make them unfit for use.

Processing

Tanks.—The workload of the X-ray department was frequently so heavy that auxiliary wash tanks had to be built in many hospitals. Wooden tanks, except those constructed of redwood, were not satisfactory. They soaked up solution; soon warped and leaked; were difficult to keep clean; and rotted rapidly under the continuous high temperatures and excessive humidity of the darkroom. In the circumstances, however, the auxiliary tanks had to be constructed of anything available that would hold water. At the 9th General Hospital, additional tanks were made of white pine from packing boxes and metal draw rods from shutter holders.

Water supply.—This hospital was fortunate in having a mountain stream immediately behind it. When the stream was dammed, clean water, in inexhaustible quantities, was piped into the hospital, at an average temperature of 79° F., with a variation of 1.7° F.

This situation was exceptional. Most radiologists, as Major Newman put it, necessarily became plumbers in Australia and learned how to attach their tanks to the complicated Australian plumbing. In New Guinea, there was no such problem because there was no plumbing. The wash tank was simply filled and emptied once daily.

The problems connected with water were twofold, supply and temperature. A supply of cool, clear water was unusual in the field, and many units located near the shore used sea water for washing their films. Clear water was used for the final washing. This plan was not too unsatisfactory when the temperature of the water could be controlled. It was not very satisfactory when it could not be.

Sea water could also be used in an emergency to compound developers and fixers. The solutions were turbid at first but became clear if they were left standing. The clear fluid could then be decanted and used.

In parts of New Guinea, wells had to be dug by hand, which was a command responsibility. It was not much of a problem, since the water table was only a short distance below the ground surface. The supply of pipe, however, was extremely limited, and water for the darkroom had to be hand-carried into it after being secured from the two-wheel trailers usually used to bring it into the hospital. The water temperature was usually high, and films were generally processed at undesirably high temperatures because of the inadequacy of the refrigeration units.

When pipes were available, it was best to bury them deep beneath the ground surface. When they lay on the top of the ground, with large sections exposed, the temperature of the water was thus permitted to become so high it was not usable.

In a number of locations, water from the central hospital supply had such a high chlorine count that it could be used only for washing; solutions had to be made from rainwater, which was almost constantly available.

The cooling units provided did not reduce the temperature of the solutions much below 85° F., and developing films in a small tank at this temperature was a tedious matter. Emulsion scratches were frequent, no matter how much care was taken. Some hospitals found that by limiting the washing to 10 minutes, softening of the emulsion could be somewhat reduced, particularly when the processing had been done at such a high temperature that chemical fog occurred on the film. At the 12th Station Hospital, in Townsville, Australia, ice was used in the water to keep the emulsion from slipping. Some departments kept their solutions cool by constantly replenishing those in use with fresh supplies cooled in the laboratory refrigerator.

In the Tropics, developer and hypo solution could be used for not more than 100 to 150 films. If an attempt was made to use the same solution for the 250 to 300 films it could have been used for in civilian practice, the films were likely to be both underdeveloped and not hardened.

When the 1st Evacuation Hospital was at Oro Bay, New Guinea, the developing tank was able to handle the rather warm water quite satisfactorily because the department had a complete processing unit, which included developing and fixing tanks and water tanks, all connected with a refrigerating unit and a pump that circulated the water and maintained a fairly constant temperature. Because of the efficient circulation system, the temperature of the water remained within the desirable maximum limit, and the excellent films produced were attributed in large part to the arrangements in the darkroom.

Capt. Wyatt E. Roye, MC, described some of the problems connected with the processing of films at the 311th General Hospital. Here it was necessary to run the cooling system constantly and to add practically no water to accomplish a temperature of about 76° F. The drainage tube was much too small and frequently became clogged, the clogging being aggravated by beer bottle labels (the ingenuity of the U.S. soldier had discovered the only cooling

system available in the hospital). It was almost impossible to control the temperature of the wash water. At high temperatures, the emulsion on the films became soft and tended to run, and the image was therefore distorted.

High humidity seemed to play the most important part in the slipping and sliding of emulsion and the resulting loss of image, but this also happened when the temperature of the wash water exceeded 85° F., as it often did, even in general hospitals in semipermanent or permanent locations.

Drying

During the dry season in Australia, the humidity was low, and drying of films presented no special difficulties. In the wet season there, and always in New Guinea and the Philippines, the high humidity and constant rain made this part of their processing a major difficulty.

The combination loading bench and drier supplied by the Army was practical and useful in temperate climates, but in the Tropics, it was one more item to crowd the darkroom, and it was frequently put outside. Units which did not have this item, and many which did, dried their films outside, on clotheslines. The films dried rapidly in the heat, but they had to be kept under constant observation because of the sudden downpours that occurred at intervals almost daily.

Some hospitals devised more elaborate drying methods. At the 17th Station Hospital, a drier was improvised consisting of a box heated by electric bulbs, with a small fan blowing over them.

Dr. Ralph C. Moore (formerly Captain, MC), asked for a description of the drying rack used at the 105th General Hospital, described it as follows:

> The film washing system consisted of a water tank, half of which was in the dark room and half in the wet reading room, with an interlocking lightproofed cover over the tank. When the cover was opened in the reading room, the cover in the dark room could not be opened, and vice versa. From the wash tank, the films were then placed in drying racks.
>
> The drying rack at the 105th General Hospital was built into a cabinet built in the fashion of a tall closet extending from the floor to the ceiling. A duct system was extended from the fluoroscopic room and fed into the bottom of the closet. The air flowed out across the films in the closet and out through the top into the room. The air was forced into the duct system by a squirrel-caged fan from an old wrecked tank and was sucked out through the top of the drying closet by another fan which was built into the top of the closet. The films were hung on racks which would hold 14 by 17 hangers each. These were placed in the closet on guides so that the racks worked like drawers. There were six of these racks, arranged one above the other in the closet. When the door of the closet was closed, the entire drying closet acted as a part of the duct system through which the air had been forced. The dry films were removed from the top and the wet films placed in the lower position. The method was perhaps crude, but it was highly efficient.

At the 9th General Hospital, Colonel Tucker and Captain Tillinghast disassembled the drier unit supplied by the Army and used the fan and the heating element to construct a drier with a capacity of 88 films. The device

was built in four tiers and had notched wood racks to hold the hangers. The heating element was placed at the bottom of the drier, and the fan, blowing outward, at the top. The air intake was placed at the bottom rear, and the incoming air came from the darkroom through a light maze made of wooden partitions and sided with pressed wood. A similar maze air vent was placed on the outside wall of the darkroom over the loading bench, and a 12-inch fan was so placed as to draw air into the room.

Handling

Identification.—Although Circular Letter No. 147, Office of The Surgeon General (*1*), clearly specified the method by which X-ray films must be identified, Major Reavis found on his tours of inspection that these instructions were frequently being ignored, particularly in the smaller hospitals. Even in the larger hospitals a variety of nonregulation methods were in use.

The 42d General Hospital had been able to purchase in Brisbane an Eastman film identification printer (photographic printer for labeling films), but most hospitals were not so fortunate. Lead numbers and letters were not readily available, and those originally supplied were soon lost. A number of hospitals in New Guinea simply wrote the patient's name on the film before it was developed. The name remained on the film, of course, and the system was quick and required no equipment beyond a pencil. On the other hand, the writing was not always easy to read, and it was sometimes entirely illegible. Typing the information on the lead foil backing from dental films was another practical method, used at the 1st Evacuation Hospital. The impression made by the keys produced enough difference in density to make a permanent record. The best of all improvised systems, however, was the use of the patient's identification (dog) tag on the film. It provided all the information necessary for identification except the film number and the date.

Records.—Since almost every hospital that had X-ray equipment also had a mimeograph, most radiologists devised some sort of report form, varying from the usual WD MD Form 55K–2, which was supposed to be standard throughout the Army, to rather elaborate forms used in some of the larger general hospitals.

Some interpretations were never recorded because the X-ray examinations were made under such unpropitious circumstances, but, in general, an effort was made to keep some sort of formal record, even if it consisted of no more than a few hurried notes. Since the handwriting of so many medical men is illegible, Major Reavis recommended that typewriters be given to all X-ray departments, or made available to them, so that all reports could be typed. In some hospitals, the radiologist dictated his findings to a corpsman, who typed them later.

The system in use at the 42d General Hospital was probably the most elaborate in the Southwest Pacific Area. It was possible because there was a dictaphone in the department, and two and three Australian civilian secre-

taries were assigned to the section at all times. All reports were made in triplicate. One copy was kept in the department files, one attached to the chart, and one kept in the film envelope. A crossfile of pathologic diagnoses was maintained, and 35-mm. microfilms were made of the films of all patients evacuated to the Zone of Interior.

Filing.—Some general hospitals kept their films on the ward as long as the patient was hospitalized except when additional examinations were required; then the films were returned to the X-ray department for comparative studies. Whenever this plan was in effect, radiographs were damaged or lost or both. Major Reavis discouraged it for this reason, as well as on the ground that radiographs cannot be read properly without view boxes, of which there were none on the wards. Only gross changes are observed when films are simply held up against daylight or other light.

In some hospitals, routine films, considered to be of no further use, were destroyed when the hospital moved.

Filing envelopes were in short supply, which led to another bad practice, that of stapling or clipping films together. Because of the heat and high humidity, films filed against each other stuck to each other. In his capacity as Acting Consultant in Radiology, Major Reavis recommended that a memorandum be issued from the Office of the Surgeon, Services of Supply, SWPA, setting forth a desirable record system for X-ray reports, at least for relatively fixed installations. He advocated the maintenance of a daybook, with each patient's name and X-ray number; an alphabetical card file system, listing all examinations made, and, if possible, summarized reports; and duplicate copies of WD MD Form 55K–2, the original being placed on the patient's chart and the duplicate in the file envelope.

Evacuation.—When patients were returned to duty from field, evacuation, or even station hospitals, their radiographs were frequently kept in storage until the hospital moved on and then were destroyed. Radiographs not properly fixed were sometimes discarded as soon as they were read because their value as permanent records was negligible, and the cleared transparent film could be put to other uses around the hospital. As in the European theater (p. 340), the ideal plan was that a patient who had to be evacuated from the area should be accompanied by his radiographs. This policy never achieved in SWPA anything like the success that it achieved in the European theater.

MAINTENANCE

Early Arrangements

X-ray departments of hospitals in or near the large cities of Australia had no serious maintenance problems. Thus the 4th General Hospital, during its entire operation in Melbourne, had its maintenance work done under contract with the Stanford X-Ray Co., Ltd., which not only made repairs as they

became necessary but also made monthly checks of all equipment. This hospital used both U.S. Army and Australian equipment.

The 42d General Hospital, in Brisbane, used the civilian service facilities of Watson Victor, Ltd., whose manager was very helpful and cooperative. The arrangement proved so satisfactory that when the hospital moved from its original location at Stuartholme to Highland Park, the contract was continued.

Recommendations for Areawide Service

The individual arrangements just described, and others like them, were extremely valuable, and the life and usefulness of X-ray equipment were definitely prolonged thereby. Units in the field, however, or distant from larger cities had no such facilities; each unit had to take care of its own equipment, by the combined efforts of the technicians and radiologists.

Major Reavis considered it imperative that some sort of maintenance and repair service be set up to keep operational equipment functioning and to repair equipment that had broken down. He specifically recommended the following plan, through channels, to the area surgeon:

1. A maintenance and repair X-ray service should be set up on an areawide basis, responsible to the chief of the Medical Supply Division but functioning under the supervision of the consultant in radiology in SWPA.
2. The repair shop should be set up and maintained in the location in which there was the greatest concentration of hospitals and should be moved forward as combat moved forward.
3. All work should be done through the base consultant in radiology.
4. In the beginning, the repair shop should be at least 20 by 30 feet, and preferably larger.
5. Ten enlisted men should be assigned to the shop, each of whom should be given intensive training in maintenance and repairs. After their training, they should be assigned to the various base sections and rotated at the discretion of the officer in charge of the shop.
6. The function of the technicians should be to install, or at least supervise the installation of, the X-ray equipment as each hospital is set up; to instruct hospital technicians in maintenance and other technical matters; and to keep supplies and replacement parts on a continuing basis.

When this system was recommended, in February 1944, there were in SWPA 10 kits of spare parts for machines and 6 kits of spare parts for tables. All of them were requisitioned several times over. Major Reavis proposed that these kits be assigned to the medical X-ray service group he had recommended and be used under their supervision rather than distributed to individual hospitals on the basis of requisitions for them.

Major Reavis also recommended that 2d Lt. (later 1st Lt.) Harry E. Bingham, MAC, be appointed to head the proposed maintenance depot. Lieutenant Bingham's qualifications admirably fitted him for the assignment. He had had 4 years of college physics, had served as chief technician in sev-

eral large civilian hospitals, and for several years had been educational director of the Buck X-Ograph Co., St. Louis, Mo. He had attended the Army X-Ray School at Walter Reed General Hospital, Washington, D.C., and had later been an instructor there and in the similar school at Fitzsimons General Hospital, Denver, Colo.

Before the maintenance depot was set up, Lieutenant Bingham, who was chiefly attached to the 29th Medical Depot Company, served as X-ray maintenance officer for Oro Bay and periodically inspected all the equipment there and in the immediate vicinity. He also surveyed and serviced the X-ray units in Milne Bay and Port Moresby, New Guinea. During the same period, he gave short courses of instruction in various hospitals, in an attempt to improve radiographic technique with the field X-ray unit.

Establishment of Maintenance Section

The maintenance and repair section recommended by Major Reavis was organized in New Guinea in October 1943, under Lieutenant Bingham's supervision and direction, though not precisely as had been recommended, since the consultant system envisaged was never put into effect. This section was charged with the installation, repair, and maintenance of electrical medical equipment in all active and forward areas of SWPA. In fulfillment of this mission, this depot, from the time of its establishment until it moved into Japan with the occupation troops, repaired and made usable many critical items of medical equipment that otherwise would have been useless. Special tools were requisitioned for this work, and necessary replacement parts were secured.

The description of Lieutenant Bingham's work is unfortunately much briefer than its value warrants, for all his photographs, records, and charts were lost in a flash flood in Batangas during staging for the final drive on Japan.

BREAKAGE AND OTHER LOSSES

Hospitals arriving in SWPA were usually equipped according to the tables of equipment, but practically always there were some losses caused by breakage, especially of heavy equipment. About 75 percent of the protective lead glass in the fluoroscopic attachment for the field X-ray table was broken in transit, and there was also a heavy loss of illuminator glass. Replacements frequently arrived in the same condition, and some hospitals were therefore never able to use these special items. When the 125th Station Hospital, for instance, reached Milne Bay, its fluoroscopic screen was broken, and it was not replaced during the 6 months the hospital operated there.

Adequate measures of protection for X-ray equipment during hospital moves were never officially devised in SWPA, and unless sections devised their own methods, damage was heavy, and there was a resulting delay in setting

up in new locations. The best results were achieved when personnel of the X-ray department supervised the packing of their own equipment. When the 17th Station Hospital moved from Australia to New Guinea, the fluoroscopic screen and the glass of the illuminating boxes were broken, apparently during loading and unloading operations. Thereafter, when this hospital moved, X-ray personnel wrapped these and other fragile items in orthopedic felt and put the box containing them in another box. Their results were excellent, and other hospitals used the same or similar plans.

There were some losses of equipment because of poor packing at the source (p. 367), some from water damage, and some from enemy action. The 49th General Hospital could do no fluoroscopic examinations at Tacloban, Leyte, Philippine Islands, because its equipment was destroyed in a raid by a Japanese suicide plane. Fortunately, it had few calls for such work in this location.

In the latter part of May 1942, the SS *Rufus King* ran aground on a sandbar while approaching the harbor entrance at Brisbane; sabotage was rumored but never proved. It had on it the equipment for nine station hospitals and three general hospitals. The boat split in half during delay in salvage operations and lashing by heavy sea. Legal proceedings, other storms, inadequate salvage equipment, and a variety of other causes further hampered unloading, and it was a long time before the cargo of the ship reached the dock. Everything had been soaked in sea water for long periods of time. Sheets, packs, and similar items could be salvaged and used, but film, X-ray equipment, and all other electric items of supply were almost entirely ruined (fig. 205, p. 607). There was no equipment available for replacement in Australia, and the X-ray and other departments of the hospitals involved were greatly delayed in setting up.

DELIVERY AND TRANSPORTATION PROBLEMS

The delivery of all supplies was a major problem in SWPA. They had to be brought into the area, then distributed to the bases requiring them, and the excess had to be stored for replacement. Items needed for replacement and repair were often delayed because poor loading of ships put high-priority medical supplies under other cargoes. They were therefore late in being unloaded, even when they were urgently needed.

Another difficulty of delivery was that ships were frequently ordered to new destinations without ever putting in at their original destinations. X-ray supplies were therefore unloaded at unexpected ports and had to be transshipped to their original destination.

There were still other problems. X-ray personnel sometimes traveled on one vessel and their equipment on several others, which did not necessarily arrive at the same time, or even at the same port. The equipment of the 144th Station Hospital, for instance, did not accompany its personnel from the Zone of Interior but arrived piecemeal, on six different ships.

Transportation within SWPA was also slow and undependable. There were four different railroad systems with four different gages in Australia. In New Guinea and the Philippines, there was no direct communication between one base and another or one port and another. Often the bases were on different islands. It was almost inevitable, for these various reasons, that hospitals would have difficulties in setting up, either because their equipment was at several different places or because they could not secure transportation for the entire outfit. The combined bulk and fragility of X-ray equipment made its transportation peculiarly difficult.

The experience of the 21st Evacuation Hospital, as set forth in its first quarterly report for 1945, is typical. It landed in Lingayen Gulf in the Philippines on 11 January 1945 and bivouacked in the outskirts of the village of Binmaley. It was ordered to establish a hospital in the vicinity of San Carlos, in Pangasinan Province. On 20 January, the hospital was opened in the Roman Catholic Cathedral and Monastery at San Carlos, from which some 50-odd truckloads of trash and debris first had to be moved. Great difficulty was encountered during the first 10 days after debarkation because of the paucity of trucks (four 2½-ton trucks and two ¾-ton weapons carriers). It was necessary, in addition to clearing the site for the hospital, to collect 100 tons of equipment from six beaches; haul it to a bivouac site and then to the hospital site; and also haul personnel, personal impedimenta, rations, water, and garbage and trash. The shortage of trucks and the total lack of ambulances proved the greatest handicap in the efficient operation of this hospital. The same difficulties were encountered on two subsequent occasions when the hospital could not be moved to sites at which it was needed because there was not enough available transportation. The radiologic section, with its bulky equipment without which it could not operate, was of course affected by all of these situations.

PORTABLE EQUIPMENT

Small portable X-ray units, which could be broken down and moved about in suitcases, were never provided in the Southwest Pacific Area. Furthermore, the portable field units with mobile bases had decided defects from the standpoint of portability. The machine issued early in the war had small wheels, which made it almost impossible to move it unless the ground was smooth; at that time, and throughout the war, concrete ramps were decidedly exceptional. The units issued later had large, rubber-tired wheels, but it was still impractical to move them over rough ground. The jarring and shaking inevitable when these machines were moved over uneven ground were responsible for a large number of breakdowns.

Portable equipment was put to frequent use. Radiographs were often requested in the operating room, to check the status of fractures. This was not too much of a problem, since the X-ray room was generally adjacent to the operating room.

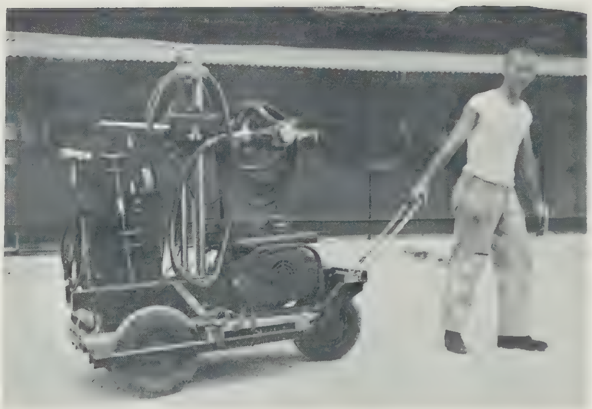

FIGURE 212.—Portable X-ray unit and power generator equipped with airplane tires, 9th General Hospital, Goodenough Island, 1944. Without some such equipment, to aid in getting the X-ray machine to the patient's bedside through mud and muck or over rough ground, a portable unit was not portable.

The examination of patients in traction on wards was a much more serious problem. It was simplified when these patients were concentrated in special wards, and greatly simplified when, as did not happen very often, the wards were connected with the X-ray room by smooth-surfaced ramps. It was also helpful to designate certain days of the week for the examination of all patients in traction on each ward. Added to other difficulties was the frequent inadequacy of electrical current in the wards on which these examinations were made.

In his report for the first quarter of 1945, the commanding officer of the 9th General Hospital stated that examination of patients in traction with the portable X-ray unit was putting too heavy a load on the X-ray department. The X-rays taken, he stated, had been obtained "with the aid of an ingenious rubber-tired juggernaut which carried both the X-ray machine and a portable generator (fig. 212). This had been carried over ground quite efficiently but we cannot ask too much even of this remarkable machine."

JAPANESE EQUIPMENT

Practically no Japanese X-ray equipment was captured during the course of the war, though some field armies were in close contact with each other. Whatever the Japanese set up was in the jungle fighting, their X-ray equipment was apparently destroyed before it could be captured. Manila was the only city of any size retaken by U.S. troops, and when it was occupied, it had practically no usable X-ray equipment in it.

The X-ray department of the Do-Ai Hospital in Tokyo was taken over

by the 54th General Hospital and, when redecorated, was made into an attractive, efficiently arranged installation. The diagnostic and therapeutic apparatus found in this hospital, however, was antiquated, and most of it was discarded except for a relatively new, shock-proof mobile unit, which could be adapted for paranasal sinus and mastoid examinations; a tilt table for fluoroscopic work; a tube stand for the radiographic table; and a cabinet of viewing boxes. All these items, after some modifications, were put to use.

REFERENCE

1. Circular Letter No. 147, Office of The Surgeon General, U.S. Army, 6 Nov. 1942.

CHAPTER XXXI

Clinical Considerations

Charles W. Reavis, M.D., and *Joseph L. Morton, M.D.*

GENERAL CONSIDERATIONS

In New Guinea and the Philippines, and even in parts of Australia, all radiologic diagnoses had to be made with the background of tropical disease in mind. This was true even if the patient had sustained a combat injury. Such diseases as malaria and dengue fever were endemic, and other diseases, such as schistosomiasis and scrub (bush) typhus, were present in certain areas. The closer the association of the troops with natives, the more likely was the military patient to be suffering with one or another of the diseases to which natives were hosts. The contacts were inevitable. In the Buna-Gona Campaign, for instance, U.S. troops lived and fought with the Fuzzy-Wuzzies [1] and contracted their diseases. U.S. Army radiologists also encountered tropical diseases in the hospitals in which, for humanitarian reasons, it was necessary to take care of the civilian and native populations.

During the Buna-Gona Campaign, almost four times as many troops were victims of disease as were casualties from enemy action. Those who crossed the Owen Stanley Mountains, in one of the most difficult marches ever performed by U.S. troops, were exhausted and half sick before the crossing was ever begun. There were nearly 15,000 U.S. and Australian casualties in the 70 days of this campaign, the majority incapacitated by disease rather than by wounds (*1*). This disproportion continued in many hospitals until the end of the war. Between 1 January and 31 March 1945, slightly less than a third of the admissions to the 54th General Hospital, Hollandia, New Guinea, were battle casualties.

Malaria was almost completely controlled by the end of the war, but earlier, it was a highly incapacitating disease. At Milne Bay, New Guinea, for a time, the rate exceeded 4,000 cases per thousand troops per year.

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[1] The Papuan natives called Fuzzy-Wuzzies were stunted aborigines who were usually tattooed but whose bodies were so frequently disfigured by the so-called basic tropical diseases (hookworn, yaws, malaria, filariasis, and scabies) that it was sometimes hard to tell where the tattoo marks left off and the marks of disease began. They were once headhunters. During World War II, they served as scouts and litterbearers and proved faithful and loyal allies. Diagnosis of any illness among them was difficult: One had to decide whether the condition was an exacerbation of some tropical endemic disease; or a complication, such as a nutritional or infectious disease, superimposed upon it; or one of the more familiar infectious or neoplastic diseases generally common to mankind at large.

BONES

Most of the radiology done in forward areas of SWPA (Southwest Pacific Area) was on combat casualties and was required to diagnose fractures and retained foreign bodies. A great deal of radiology was also done in rear areas, in which definitive orthopedic surgery was performed.

The requirement in the forward area, where much of the radiology was done by poorly trained or untrained personnel, was to produce a readable radiograph. The conditions under which the examinations were made frequently precluded any more exacting criterion. It was stressed to all personnel that when a radiograph of a bone was made, at least one joint should be included. It was also stressed that all aspects of the bone should be studied, including the cortex, medullary area, articular surfaces, articular spaces, and the adjacent soft tissues.

The field hospital was the farthest forward unit in which X-ray facilities were provided. Many surgeons expressed the opinion that it would be useful if clearing companies could also be provided with minimum X-ray equipment, on the ground that positive knowledge of a fracture or of the location of a retained foreign body in a wound of the chest or the abdomen would be useful in triage and management.

Combat-incurred fractures were generally more extensive, more likely to be comminuted, and more often displaced than those seen in civilian practice (figs. 213–215). Open reduction was often required in general hospitals during the New Guinea campaign for fractures seen from 4 to 6 weeks after wounding, with malposition and malunion. In most of these cases it was too late for traction to be satisfactory. It was not uncommon to find osteomyelitis in some of these fractures at this time. Gas gangrene, however, was extremely uncommon (fig. 216).

There was frequent comment on the delayed and deficient callus formation observed in many combat-incurred fractures. It was thought that the causes might be both climatic and dietary.

There were numerous noncombat fractures, both simple and comminuted, as might be expected in such large concentrations of troops and so much traffic.

The dispensary of the 51st General Hospital, whose X-ray department averaged 100 or more examinations a day of Army, Navy, Air Force, Marine, Seabee, and Merchant Marine personnel, reported two extremely common types of noncombat fractures. One was a fracture of the calcaneus, caused by stepping off uneven ground in the dark, digging in the heels during training jumps, and handling uneven, heavy, and awkward A-frames. The Achilles tendon was usually involved. The other was a carponavicular fracture, caused by handling and loading heavy bundles on ships in Pancake Bay.

Some fractures of the bones of the arm, as well as of the skull, were caused by falling coconuts (p. 648).

There was no known or recorded instance of a march fracture in the many thousands of examinations of the bones of the foot in the Southwest Pacific.

FIGURE 213.—Comminuted fracture of left hip from gunshot wound. Fractures of this kind were common in the Southwest Pacific Area. Healing was generally satisfactory, though sometimes rather slow.

The injury, while not frequent, was observed in the United States (*2*). The explanation was thought to be the differences in the training programs in the two areas, as well as differences in the resiliency of the terrain.

A number of anomalies of various sorts were observed (fig. 217), most of them not incapacitating.

Pneumoarthrography

As in the European theater (p. 468), pneumoarthrography was a popular radiologic technique in SWPA. In all, the 4th General Hospital made 465 such examinations, in which there were found 133 abnormal menisci; 67 popliteal (Baker) cysts; 39 instances of osteomyelitis; 22 instances of osteochondritis dissecans of the knee; and 3 giant cell tumors. The procedure was without risk and therefore was used routinely at this hospital in all suspected internal derangements of the knee. It was of particular value in the diagnosis

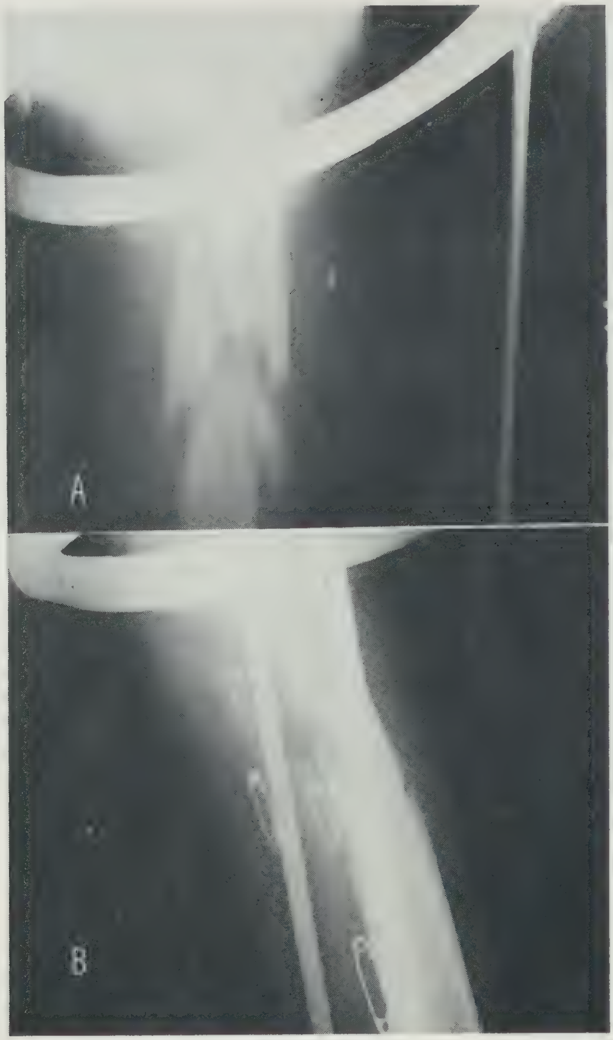

FIGURE 214.—Compound comminuted fracture of shaft of right femur from gunshot wound. The patient is in a Thomas splint. A. Anteroposterior roentgenogram showing comminution of proximal end of shaft and multiple opaque foreign bodies in soft tissues. B. Lateral view.

of abnormalities of the menisci, bursa, and fat pads, which accounted for over two-thirds of the major lesions in these derangements.

Capt. (later Maj.) Isadore Meschan, MC, and Lt. Col. Wilbert H. McGaw, MC, made a study of 315 cases at this hospital in which the following technique was used before surgery (fig. 218) (*3*):

From 80 to 100 cc. of oxygen was injected under gentle pressure into the

FIGURE 215.—Gunshot wound of right hand with comminuted fractures of second, third, and fourth metacarpal bones. Note multiple minute metallic foreign bodies in the area.

joint space, after preparation of the field and infiltration of 2 percent cocaine down to the joint capsule. The point of injection was the lateral aspect of the knee, below the junction of the quadriceps tendon with the superior articular margin of the patella, which was displaced laterally to facilitate insertion of the needle. As the oxygen began to enter the joint cavity, the operator could feel and see the swelling of the suprapatellar bursa. The injection was continued until the patient complained of pain and slight positive pressure in the joint, then the needle was quickly withdrawn and finger pressure applied over the point of injection for several minutes, to seal the opening in the bursa. When the patient was placed in the prone position, the movement facilitated the distribution of oxygen throughout the joint.

The medial and lateral ligaments were stretched by appropriate medial and lateral compression of the knee joint by a wooden board spreader.

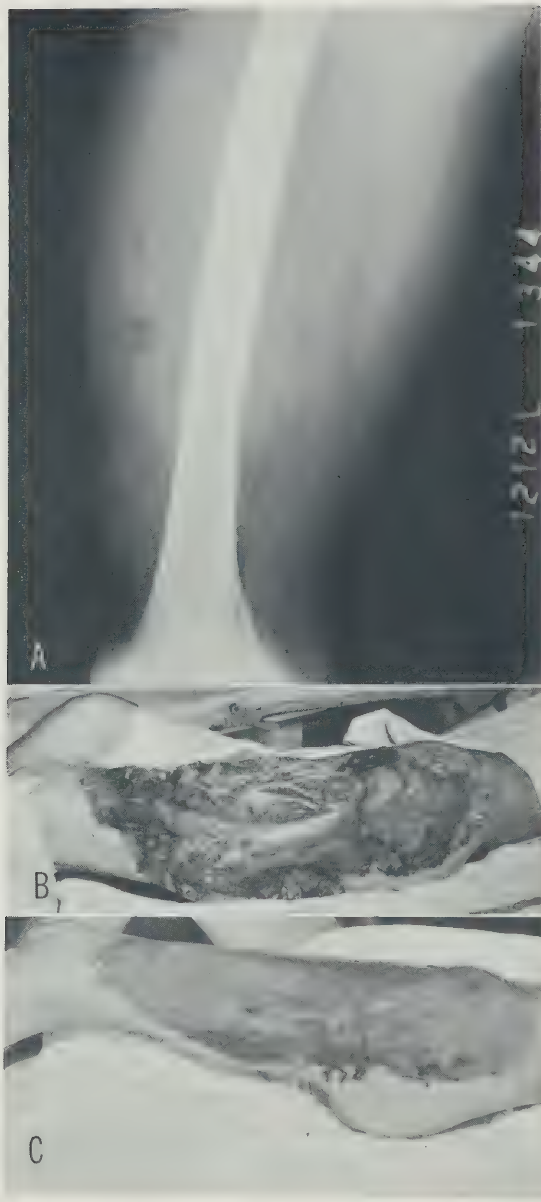

FIGURE 216.—Gas gangrene following gunshot wound of thigh. A. Oblique view of lower thigh showing large amounts of gas in tissues. B. Wound after secondary debridement. C. Wound 3 weeks later, showing good progress toward healing.

FIGURE 217.—Unusual, bilaterally symmetrical anomaly of great toes. Anomalies of various sorts were fairly frequent in the Southwest Pacific Area, but one of this type obviously would not interfere with a man's ability to perform full duty overseas. A. Photograph of feet. B. Anteroposterior radiograph.

For the anteroposterior and posteroanterior views the factors used were 55 kvp., 15 ma., ¼ second at 30 inch distance, par-speed screens. For the lateral projection the factors were the same except that 51 kvp. was used instead of 55 kilovolt peak.

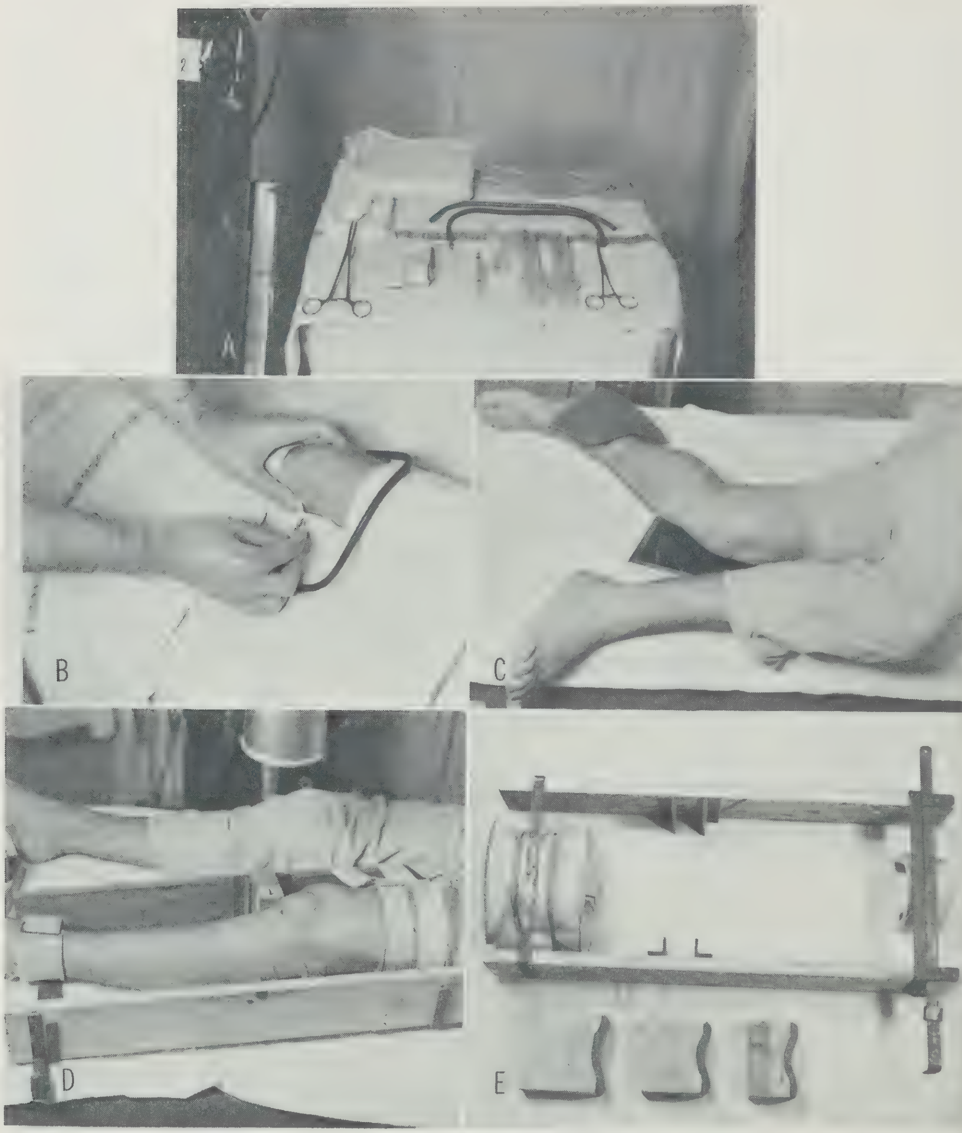

FIGURE 218.—Technique of pneumoarthrography. A. Surgical tray, with necessary equipment. B. Lateral insertion of needle at level of upper margin of patella. C. Taking of lateral roentgenogram. D. Taking of anteroposterior roentgenogram with aid of board spreader. E. Board spreader.

The technique just described gave excellent results at the 4th General Hospital. The generally similar techniques used at the 42d General Hospital and other hospitals in SWPA for pneumoarthrography also gave satisfactory results.

Civilian-Type Diseases

In addition to fractures and foreign bodies, a certain number of bone lesions were diagnosed, sometimes during examination of combat injuries, sometimes on routine examinations, and sometimes on examinations for specific complaints. These lesions included enchondromas, manifested by round, cystlike lesions in the distal metaphyseal area; exostoses and osteomas, manifested by the outgrowth of bone along the metaphyseal area; and nonossifying fibromas. None of these lesions were incapacitating, and most of them required no treatment. More serious lesions were occasionally encountered, such as the bony manifestations of some blood dyscrasia or leukemia, or even a malignant bone tumor.

All of these lesions were naturally unusual. The soldiers examined by radiologists in SWPA were all individuals who had undergone medical examinations, which in most instances included radiographs of the chest, before they were accepted for service, and it was not likely that many of them would be found with bony lesions or other abnormalities so soon after induction.

Various types of arthritis were diagnosed by radiography, and some cases of osteochondritis of the joint surfaces were seen. Such conditions might be expected. When men were subjected to circumstances under which they had not previously lived, such as life in the Tropics and jungle warfare, it was not unlikely that certain bodily changes would occur, and that they would affect the skeletal structures as well as other parts of the body.

Patients with osteochondritis and arthritis were usually no longer useful for combat and were evacuated to the Zone of Interior.

Yaws

Circumstances in the Southwest Pacific were not propitious for research, and followup of casualties was almost impossible. Nonetheless, some investigations of value were made, among them a study of yaws in natives at the 168th Evacuation Hospital by Capt. (later Maj.) Walter J. Stork, MC, and Maj. Carl W. Fleet, MC, which covered all aspects of this disease, including etiology, pathogenesis, pathologic process, clinical picture and therapy, as well as the radiologic aspects (fig. 219). While only the latter data are pertinent in this account, the general facts of the disease may be briefly summarized as follows:

Tropical yaws, a spirochetal infection, is the commonest disease of the skin, bones, joints, and tendons encountered in the native population of the Southwest Pacific Area. It occurs chiefly in races living in socially low level areas in which sanitation is completely ignored. The extreme rarity of yaws among U.S. troops, in spite of their close contact with natives on many occasions, was clear evidence that poor sanitation and hygiene play a prominent role in the spread of the disease.

The most astonishing fact about yaws is that in spite of massive involve-

FIGURE 219.—*See opposite page for legend.*

ment of the soft tissues and bones, the victims are often able to carry on their normal duties and appear to be only slightly incapacitated.

Any slight abrasion of the skin is a suitable portal of entry for *Treponema pertenue*, which is transmitted by contact or is carried in by insects and fomites. A minor cut or scratch can become a huge ulcer in 5 or 6 days, and in a few months may involve an entire extremity. Trauma cannot be discounted as a precipitating factor. Maggots are frequently present in the lesions, and secondary infection is the rule. Many of these patients also have other diseases, such as chronic malaria, amebiasis, and helminthiasis. Apparently, once the process begins, the cutaneous ulceration spreads to the subcutaneous tissues and into deeper structures by continuity. The tendon sheaths, the bones, and, in contrast to syphilis, even the articular margins are involved.

Differentiation of yaws from syphilis is made clinically and confirmed in the laboratory by darkfield and Kahn tests. The radiographic picture of the disease is difficult to differentiate from syphilis if only radiographs are available, though easy when a clinical history is available. An important point of differentiation is that the two conditions are not common in the same area.

Treatment is by arsenicals and is on an outpatient basis unless there are special reasons for hospitalization. In World War II, there would not have been enough beds to hospitalize all the patients who were seen. In one respect, outpatient treatment is unfortunate because the response to arsenicals is usually prompt and remarkably good, and native patients therefore often do not return until there is a recurrence of symptoms. This is likely, and the common practice of dismissing patients after a few injections is to be condemned, particularly when bone lesions are present; when they are, and treatment is not completed, recurrences can be expected within a few months.

The study made at the 168th Evacuation Hospital by Major Stork and Major Fleet covered 886 patients with both the typical type of yaws and the juxta-articular type, the hyperkeratotic type, and goundou, gangosa, and so-called crab yaws.

Osseous changes.—Bony changes in tropical yaws are both destructive and proliferative. Bone and joint changes were present in about a quarter of the 886 cases of yaws studied. While the disease progresses more rapidly and is more painful than syphilis, the bony structures are usually attacked slowly and rather late, and there are often no symptoms referable to the bones. In

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FIGURE 219.—Yaws in the Southwest Pacific Area. A. Nodular skin lesions on legs. B. Posteroanterior and lateral views of legs of patient shown in view A, showing characteristic lesions of tibia and fibula. Note lacy periosteal proliferation and condensation of underlying tibia. C. Anteroposterior and lateral views of radius and ulna of patient shown in views A and B. Note cystic changes under cortical proliferation. D. Anteroposterior and lateral views of tibia and fibula showing bony sclerosis and underlying cystic changes. E. Anteroposterior and lateral views of elbow showing characteristic nodular, lacelike bony proliferation, chiefly in humerus. Ulna shows cortical thickening. F. Yaws of leg. G. Anteroposterior view of tibia and fibula of patient shown in view F.

some active ulcerative types of disease, however, a destructive process simulating osteomyelitis may be present in a few weeks.

The lower extremity, especially the tibia, was more frequently involved in this series of cases than any other part of the body; the bones of the hands and of the face were also affected. These observations were in accord with general observations.

As the disease progresses, particularly in cases in which it progresses rapidly, extensive periostitis and osteitis occur. Dactylitis develops when the hands and feet are affected. Healed ulcers, which usually are painful, are likely to be associated with cortical thickening and other changes in the underlying bone structures. In any longstanding case, the cortex is eventually involved.

The following conclusions were considered warranted from the radiographic observations made in this series:

1. The primary bone lesion in tropical yaws is a cystic destructive process, with surrounding areas of sclerosis, new periosteal formation, and cortical thickening, the changes varying with the chronicity of the disease. Proliferative nodular periosteal involvement is generally characteristic.

2. The characteristic oval osteolytic areas usually show up as circumscribed areas of reduced density in the long axis of the shaft of the affected bone. They vary in size, usually in proportion to the size of the overlying soft-tissue lesions. They occur in the articular surfaces most often exposed to trauma, such as the femoral condyles, the ankles, and the wrists.

3. Patients with a history of several remissions and recurrences usually show extensive, irregular bony proliferation; reconstruction of cancellous tissues; considerable bone condensation; and occasional osteolytic areas. In advanced and chronic cases, there is alteration of the cancellous structures, with trabeculation; dense, irregular bony thickening; and irregularity of the outline of the shaft, especially the shaft of the tibia. Spiculation with indications of cuffing is seen in the bones in which there is least destruction.

4. Widening of the cortex and increased density, with sclerotic sequelae, are often seen between areas of rarefaction in cancellous bones and bear out the chronicity of the disease.

5. Extensive osteoporosis is common.

6. Acute angulation of the shaft at the area of greatest bone condensation is evidence of an unrecognized pathologic fracture.

7. Tapering of the heads and the distal tips of the phalanges and metatarsals is common. When the destructive process invades the bones of the foot, the metatarsophalangeal joints are disarticulated and eroded.

Complete destruction of several carpal bones, with loss of normal architecture of the entire wrist, was seen twice in this series. The destructive process was confined to the wrist, but a lacework type of periosteal proliferation extended along the distal radius and ulna.

8. Localized areas of decreased density were sometimes seen only in a single joint, most often a metatarsophalangeal joint. Isolated, punched-out

lesions were also sometimes seen in single bones, usually near the epiphyseal line, but multiple involvement was most frequent. Unilateral involvement was most frequent in the upper extremities and bilateral involvement in the lower extremities.

9. The saber shin is characteristic of the tertiary stage of the disease. Cortical destruction, simulating abscess formation, may occur bilaterally in this bone.

10. Juxta-articular yaws, crab yaws, and the keratotic type show the least bone destruction of any variety of yaws. The usual radiographic findings are only a mild periostitis and cortical thickening. The clavicle and occasionally the metaphyses of the bones of the extremities may show osteolytic lesions.

In goundou, there is exostosis of the facial bones, with final obstruction of the nasal passages. In this variety of yaws, the response to arsenicals is slow, and the surgery often necessary may be difficult because of the surrounding infection. In gangosa, the nasal septa and softer nasal bones may be absorbed in the destructive process.

FOREIGN BODIES

Techniques

Since a large part of the work of all X-ray sections in the Southwest Pacific consisted of the identification and localization of foreign bodies, it was logical that almost all of them possess the foreign body localizer attached to the field unit. Some hospitals had more than one of them. This piece of equipment, however, was universally disliked (p. 72). Some radiologists, having seen it in operation, never had their sets unpacked. Others discarded the apparatus after they had used it once or twice.

The most practical method of localizing foreign bodies in the soft tissues was to make plain radiographs of the part in standard projections, to determine the relation of the retained objects to the adjacent bones and joints. Lead markers were placed on the skin, and the projections were made in planes perpendicular to each other. In fact, it was not long before most surgeons simply requested anteroposterior and lateral projections of the affected area, being able to secure from these views all the information they needed.[2]

Many radiologists, after gross localization of the retained object by this means, inserted a needle pointing to it, under fluoroscopic control. At the 35th General Hospital, after the object was localized under the fluoroscope, a long needle attached to a syringe filled with Novocaine (procaine hydrochloride) was inserted in the area under interval fluoroscopic vision until the point of the needle touched the object. The syringe was then removed, the patient

[2] Major Morton, in a report from the 42d General Hospital, called attention to Case's World War I teachings about the localization of foreign bodies: That they could be localized anatomically, by identification of tissue spaces and planes, and not by centimeter-depth and at right angles.

taken back to the operating room, and an incision made alongside the needle down to the object.

The removal of foreign bodies under the fluoroscope was a time-consuming, dangerous procedure, which Major Reavis condemned whenever he found it in use. Maj. (later Col.) Vernon L. Bolton, MC, describing the technique of fluoroscopic-radiographic localization in use at the 1st Evacuation Hospital in World War II, said frankly that in the light of postwar knowledge he thought this procedure had been unwise. Just as much information could have been gained, he concluded, from two well-positioned films taken at 90 degrees.

Head and Eyes

Foreign bodies lying intracranially were generally localized by posteroanterior and lateral films. Major Morton, profiting by what he had learned from Dr. Artur Schüller (p. 649) in Melbourne, was able to locailze and remove a spent Japanese tracer cap located just lateral to the orbit.

A patient with an intraocular foreign body seen in a forward hospital was evacuated as rapidly as possible to a station or general hospital that had a Sweet localizing apparatus and an ophthalmologist on the staff capable of removing the object. The military experience paralleled the prewar civilian experience: Only by this technique could a small, opaque foreign body in the eye be localized. When trained radiologists were available in forward units, they used the multiple exposure Waters technique to determine whether a foreign body in the eye was in the eyeball or outside of it. Two anteroposterior exposures were made on the first film, one with the patient looking up and the other with him looking down. A similar double lateral exposure was made with the patient looking first to the right and then to the left.

Chest

Foreign bodies in the chest were numerous. During one 6-month period at the 27th General Hospital, 5 percent of the 4,040 casualties admitted, from 1 to 6 weeks after wounding, had wounds of the chest, in many instances with the missiles still in situ.

Posteroanterior, lateral, and stereoscopic exposures were made to determine the presence and location of foreign bodies; the extent of associated injuries to the ribs, sternum, and spine; possible pulmonary involvement; possible mediastinal involvement; and the status of the pleural space. The examinations were best made with the patient upright. Grid films of heavier exposure were necessary to detect rib fractures and to identify foreign bodies that might be concealed by mediastinal structures. Foreign bodies in this location were likely to be overlooked if this technique was not used.

In some instances of retained foreign bodies, a diffuse area of infiltration was observed in the lungs. Later, this area became circumscribed and either spherical or ovoid. Still later, it gradually diminished in size and regressed.

It was interpreted as a hemorrhagic infiltration that underwent organization and then resolution.

Lt. Col. William A. Evans, Jr., MC, in a study of the radiologic aspects of chest wounds, stressed the following points:

1. Many times there is little or no evidence of reaction to a foreign body in the lungs or the pleura. In most cases, however, hemothorax or pneumothorax is present.

2. Traumatic lesions of the lungs tend to be small and well circumscribed, and to undergo eventual resolution.

3. Small amounts of air and blood in the pleural space are rapidly absorbed, especially when they are handled by early, frequent aspiration.

4. Blood in the pleural space acts as an irritant, encouraging exudation, the formation of large fibrin clots, and pleural thickening. The exudate tends to become encapsulated, often posteriorly, and multiple pockets form. Infection then occurs, even while patients are on sulfonamide or penicillin therapy. If the blood is not completely removed within 10 days, convalescence is greatly prolonged, and irreversible changes may occur.

5. A large cardiac shadow suggests involvement of the pericardium and development of pericardial effusion.

Abdomen

Most patients with wounds of the abdomen were operated on in mobile (portable) hospitals, which had no X-ray facilities. When patients with abdominal wounds did reach hospitals with provision for X-ray examinations and definitive study, the most important radiologic procedure was to make a film with the ray passing horizontally through the abdomen, the patient being kept in the same position in which he was received in the department. If he were turned or were moved to the upright position, very minute quantities of air present might not shift about quickly enough to be visualized under the diaphragm. Air can be readily visualized in the flanks, and its presence anywhere in the abdomen was assumed to indicate a perforation.

It was necessary to bear in mind that, in some instances, a visceral perforation might be sealed off immediately after wounding and then leak again, particularly if evacuation had been over rough and rugged roads. When, therefore, any patient with an abdominal wound was received, the correct procedure was immediate examination by anteroposterior and lateral views to determine the presence and location of a possible foreign body.

One of the really remarkable foreign bodies observed in SWPA, at the 42d General Hospital, was a large tablespoon in the stomach of a neuropsychiatric patient. Radiographic examinations on this indication was undertaken with considerable skepticism but it proved unjustified: The film showed the spoon in the stomach, with the bowl lying toward the pylorus (fig. 220). How the patient managed to swallow it remained a mystery. Psychiatric patients, incidentally, were often difficult to X-ray.

FIGURE 220.—Spoon swallowed by neuropsychiatric patient and removed from stomach at 42d General Hospital. Other opaque areas in abdomen represent other swallowed foreign bodies.

REGIONAL RADIOGRAPHY

Head

Skull and brain.—Trauma was the most frequent indication for radiographic examinations of the head, which were carried out in both forward and rear areas for both combat and noncombat injuries. Many fractures of the cranial vault were associated with fractures of the facial bones and the jaw. Depressed, linear, and stellate fractures of the skull were seen (fig. 221), as well as bizarre types caused by explosives and by the cutting instruments used in occasional close contact warfare (fig. 18, p. 529). When the 35th General Hospital was staging at Milne Bay, its first casualties were men with

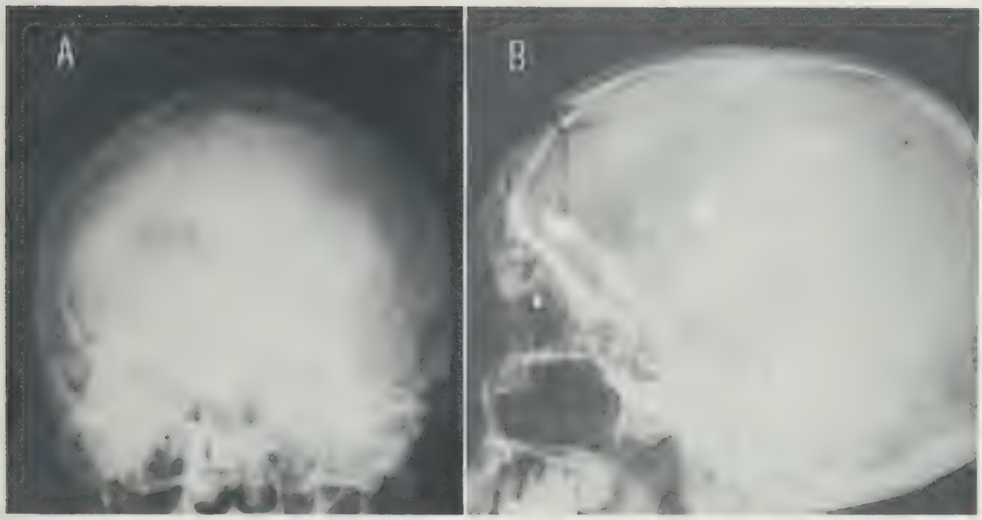

FIGURE 221.—Penetrating wounds of skull causing irregular fracture of frontal bone. Note multiple intracranial shell fragments. This type of injury was common in troops in the Southwest Pacific. A. Anteroposterior view. B. Lateral view.

fractures of the skull caused by falling coconuts. Other hospitals in New Guinea also reported fractures from this cause, a number of which were fatal. Traumatic pneumatoceles were sometimes seen in association with fractures.

In a total of 690 examinations of the head in the X-ray section of the 4th General Hospital, there were 56 fractures of the skull and 13 space-occupying lesions of the brain. Shifting of the ventricular systems was seen in subdural hematomas and in neoplasms. Other conditions revealed by radiography at various hospitals in SWPA included osteomas, osteomyelitis, Paget's disease, and platybasia.

When the radiologists on the staff of the 4th General Hospital were reading films at the Royal Prince Alfred Hospital in Melbourne, Australia (p. 572), it was not unusual to find *Echinococcus* cysts, some of the brain and others in the lungs, abdomen, and bones.

At the 42d General Hospital, which had a well-trained and aggressive neurosurgeon on its staff, as well as at certain other general hospitals, pneumoencephalography and ventriculography were done. The radiographs were usually quite adequate. Cerebral arteriograms were made at the 49th General Hospital while it was stationed in Manila.

Major Morton recalled that while he was in Melbourne he had had the privilege of meeting Dr. Schüller, the famous Viennese neurologist, who had been the first to put radiology of the head on a firm basis and who had described the disease that bears his name (Hand-Schüller-Christian disease).

Dr. Schüller showed Major Morton films of foreign bodies lying just behind the outer rim of the orbit, although both anteroposterior and lateral

views suggested that they were in the cranial cavity. This information was later to prove extremely useful to Major Morton, as already noted (p. 646). Dr. Schüller also demonstrated films of skull fractures in childhood, in which healing had occurred with widening of the traumatic defect, an observation that had not yet appeared in the literature.

Sinuses and mastoids.—All radiologists in SWPA reported an unusually high incidence of sinusitis. Between 10 April and 30 December 1943, the 4th General Hospital, Melbourne, Australia, made 1,428 examinations on this indication and found sinus disease in 1,038; mucoceles or polyps were found in 60 other radiographs. Over the 2-year period ending in October 1942, the 42d General Hospital made 1,299 sinus examinations, exclusive of those made with Lipiodol. The latter type of examination was very popular at this time, which was understandable, for it clearly delineated thickened lining membrane, as well as polyps and mucoceles.

Allergic sinusitis was often observed. In many of these cases the membranes were so swollen that they occupied almost the entire sinus cavity. Cysts, small osteomas, and cholesteatomas were observed in about the expected numbers. The X-ray department at the 27th General Hospital reported an instance of sclerosing osteitis about the maxillary sinuses.

Otitis externa was an extremely common condition in the Southwest Pacific. Frequently, the canal was so swollen and engorged that the radiologist would be requested to assist in differentiating this condition from otitis media and mastoiditis. In all such instances, the radiographs were negative.

Chest

Because of combat wounds, the abnormally high incidence of respiratory infections, and the necessity for many thousands of routine examinations in troops, native populations, and prisoners of war, in SWPA more radiographic examinations were made of the chest than of any other part of the body.

Tuberculosis.—Tuberculosis was seldom observed in U.S. troops, though the incidence increased somewhat when they moved from Australia to New Guinea. The disease was occasionally observed in merchant seamen and Allied personnel, and the incidence was quite high in internees and prisoners of war held by the Japanese. There was also a high incidence in the native populations of the various islands, particularly the Philippine Islands, but less than had been expected among the Japanese. In a group of 200 Japanese girls undergoing medical examination before employment by the Army, the frequent scarring suggested by the literature was not found, perhaps because this was a selected group.

The low incidence of tuberculosis in U.S. personnel was established by a number of radiologic surveys. Early in 1944, chest radiographs were made of all officers, nurses, and enlisted personnel of the 42d General Hospital. Only 9 of the 597 examinations were positive. Two nurses had minimal soft lesions in the right infraclavicular area, and seven enlisted men also had early

FIGURE 222.—Advanced bilateral tuberculosis with large cavities.

lesions. In a similar survey conducted during July and August 1945 at the 80th General Hospital, Manila, P.I., three enlisted men were found to have minimal active lesions.

Capt. Wyatt E. Roye, MC, a thoracic surgeon assigned to the 311th General Hospital as assistant radiologist, reported on the incidence of tuberculosis in Philippine personnel in the Manila area. At this hospital, the X-ray load was from 75 to 90 patients per day. The incidence of tuberculous lesions among Philippine guerrillas was 25 percent, and while it was lower among civilian employees and officer candidates, the final rate of presumably active tuberculosis in this region was a "staggering" 16 percent. Since the Quezon Institute was occupied by the 80th General Hospital, there was no available hospitalization for civilians with tuberculosis. Two Philippine physicians, equipped with a fluoroscope and a broken-down truck, were carrying the entire control program for the Manila area.

Although tuberculosis was not frequent in SWPA in general, it was observed that the tendency was for early infiltration to advance very rapidly to cavitation (fig. 222). These lesions were of the exudative type, in which

fibrosis occurs slowly. Involvement of the contralateral lung was sometimes observed within 2 weeks.

Pneumonia.—Sporadic episodes of atypical pneumonia frequently occurred in SWPA. While the 144th Station Hospital was at Tarlac in the Philippines, in the summer of 1945, nine cases occurred in a single regiment of the 25th Infantry Division, and two of the nine were fatal. When the 227th Station Hospital was at Milne Bay, similar small epidemics occurred on several occasions, and it was noted that they almost invariably coincided with the arrival of a troopship from the United States.

These primary atypical pneumonias were believed to be of virus origin. The process was fulminating. There was rapid, diffuse, lobular spread throughout both lung fields, with a tendency toward confluence of the lobular infiltration. The radiologists at the 42d General Hospital observed cases in which pleural involvement and atelectasis predominated and commented on the "fluffy, cotton-ball appearance about the descending vascular trunks and the diffuse, poorly defined borders of the lesions."

When complications developed, the interpretation of the radiographs was sometimes difficult. One patient observed at the 4th General Hospital in New Guinea had a diffuse pleural reaction, with evidence of fluid, following radiographically proved atypical pneumonia, and an apparent diaphragmatic involvement suggestive of subdiaphragmatic abscess. Neither the radiologist nor the clinician could explain the findings. The man died, and autopsy, unfortunately, was not performed.

In the spring of 1945, the 27th General Hospital, in cooperation with the 19th Medical General Laboratory, studied a series of natives in the Philippines who apparently had virus pneumonia. About 40 percent of the radiographs showed a small, rounded elevation of the right leaf of the diaphragm on the medial border, not unlike the findings in subdiaphragmatic or subhepatic abscess. This was an unusual finding. The common picture of atypical pneumonia, as already pointed out, is either diffuse infiltration throughout a localized area of the lung field or the area of infiltration seen in any other types of pneumonia.

Other conditions.—The incidence of bronchiectasis was no more than average. Most station and general hospitals used Lipiodol for diagnosis (fig. 223). There was an occasional reaction. One medical officer who had been overseas for 3 years and had developed a chronic cough was sent to the Zone of Interior almost as an emergency not because of his extensive bronchiectasis but because of his reaction to the iodine in the contrast medium.

Two highly unusual cases were observed at the 27th General Hospital. The first was a rupture of the leaf of the left diaphragm, with herniation of the stomach and part of the spleen into the thoracic cavity. The second was massive fibrosis of both lungs, the fields being almost 90 percent obliterated.

An unusual number of patients with spontaneous pneumothorax were observed at the 42d General Hospital. Thorough investigation revealed no

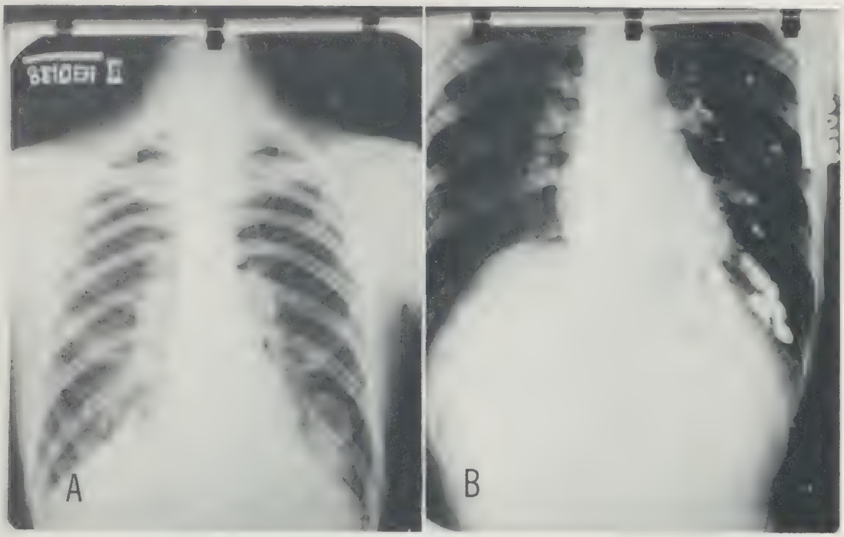

FIGURE 223.—Saccular bronchiectasis, which was observed with some frequency among troops in the Southwest Pacific Area, though the incidence was probably no greater than among men of the corresponding age group in civilian life. A. Posteroanterior view of chest showing infiltration in right base. B. Same after instillation of Lipiodol, which demonstrated saccular bronchiectasis.

evidence of active tuberculosis, and all were returned to duty. Lung abscess (fig. 224) was a fairly common complication of various chest conditions in the early months of the war but was seldom seen after penicillin became available.

Boeck's sarcoid was only occasionally observed. There were few Negro troops in SWPA, and an extremely low incidence of this condition would therefore be expected.

Azygos lobes were observed with usual infrequency, but, strangely enough, two patients with pleural effusion in the base of this accessory lobe were treated at the 27th General Hospital.

One of the most interesting cases observed was an instance of bagassosis (bagasse disease) in a Negro soldier from Louisiana. Clinically, this subacute febrile disease is characterized by shortness of breath. The radiograph showed diffuse, extremely finely reticulated interstitial pneumonia, slightly more marked in the lung bases, which are normally the more fully aerated portions of the lung. There was no cavitation, no masses or nodules, and no evidence of enlarged hilar nodes. The findings were consistent with pneumonoconiosis.

The correct diagnosis of bagassosis was made by Capt. (later Maj.) Charles L. Black, MC, a graduate of the Louisiana State University School of Medicine, New Orleans, who suspected the condition when he studied the films and confirmed it when he elicited from the patient the story that he had

worked for 3 years in a Louisiana sugar mill baling bagasse. Bagasse is the stalk of the cane left after expression of the juice, and large, conglomerate pulmonary masses may result from long-continued inhalation of the dust from it. The disease is usually self-limited; treatment consists of removing the patient from exposure to the etiologic condition.

New growths were occasionally observed (figs. 225 and 226).

Tropical diseases.—A few cases of pulmonary paragonimiasis (lung fluke) were observed. Infection by *Paragonimus westermani* is ordinarily believed to stimulate active pulmonary tuberculosis, but this sequence was not observed in these cases. Radiographic examination revealed multiple cystic areas, up to 1 cm. in diameter, the thickness of the wall of the cavity varying with the chronicity of the disease. In some cases, multiple pulmonary nodules represented a fibrotic tissue reaction about the eggs, which measure about 50 by 85 microns. As in active pulmonary tuberculosis, the apices were most frequently involved. Clinically, the disease was characterized by abundant brownish sputum and more or less hemoptysis. Diagnosis was confirmed by finding the eggs in the sputum, feces, or both.

According to Major Morton, lung fluke was observed in natives of southern Luzon, though not in the northern part of the island, and was also observed in the islands farther to the south. Philippine physicians showed interesting radiographs of chronic cases. One case of this disease was observed in a U.S. soldier at the 168th Evacuation Hospital.

Patients with schistosomiasis were observed in various hospitals in New Guinea and the Philippines, some with small chest lesions presumably caused by the parasitic infection, although the principal clinical feature of this disease is terminal hematuria and cystitis. Since the literature contained nothing specific on the radiographic findings in this disease, the X-ray department at the 27th General Hospital undertook chest examinations on all suspected cases. Fifteen of the forty patients examined had ova of *Schistosoma japonicum* in the stools, and their histories, which were developed in the course of their illnesses, were suggestive of exposure.

The characteristic chest radiographic findings consisted of diffuse bilateral involvement of nearly all lobes, with scattered nodules of increased density in the interstitial fibrous tissue. The following criteria of diagnosis were agreed on:

1. Increase in the size and density of the perihilar shadow.
2. Striations of increased density radiating from the hilum into the pulmonary parenchyma.
3. Small, indefinite nodules, characteristic of calcification, scattered throughout the pulmonic fields and along the course of the striations.
4. Sparing of the apices in all cases, with the pulmonic fields the most frequent area of involvement.

In a case observed at the 361st Station Hospital, it was thought that the pulmonary findings, which suggested those of Ayerza's disease, might be secondary to a proved infection of *Schistosoma haematobium*. Additional

FIGURE 224.—Abscess of left lower lung. Note large amount of fluid present.

studies showed them to be the result of extensive parasitic involvement of the pulmonary arteries.

Capt. (later Lt. Col.) Horace D. Gray, MC, after his return to the Zone of Interior, became chief of the X-ray service at Moore General Hospital, Swannanoa, N.C., where considerable followup work was being done on troops returned from SWPA, under the direction of Col. Joseph M. Hayman, Jr., MC. The X-ray department made a number of barium enema studies on patients with schistosomiasis, in an attempt to demonstrate the lymphatic changes which occur about the cecum. By the time the studies were made, however, the patients had been under treatment for several weeks, and no changes were demonstrable.

Chest radiographs were made at the 17th Station Hospital by Maj. Ernest B. Newman, MC, on 50 truck drivers who were exposed to heavy dust while hauling supplies and other materials from the eastern coast of Australia to Darwin, the most northern point, which was being used as an airbase for attacks on New Guinea. No significant changes were found. The roads were extremely rough, and several drivers complained of hematuria, but pyelograms failed to reveal any abnormality.

Figure 225.—Posteroanterior view of chest showing nodular mass representing primary neoplasm of lung. Patients presenting any neoplasms were evacuated at once to the Zone of Interior for more precise diagnosis and therapy.

Major Morton made a number of observations on chest findings in tropical diseases at the Royal Prince Alfred Hospital in Melbourne, where he assisted in reading radiographs. Here the professor of neurology at the University of Melbourne showed him 17 radiographs of the chest taken on patients with torula meningitis. The pulmonary lesions were typical, but even after the war they were not well recognized.

While he was in New Guinea, Major Morton also observed a number of patients with bush typhus who had hazy, moist chests, with changes similar to those characteristic of Rocky Mountain spotted fever and murine typhus. The changes did not take the form of true lesions. They were limited to hyperemia and cardiac dilatation, with fine, ill-defined focal beading of the lung markings. These were changes that Major Morton had always considered representative of capillary lesions or some other vascular lesion.

The native Australians with filariasis whom Major Morton observed

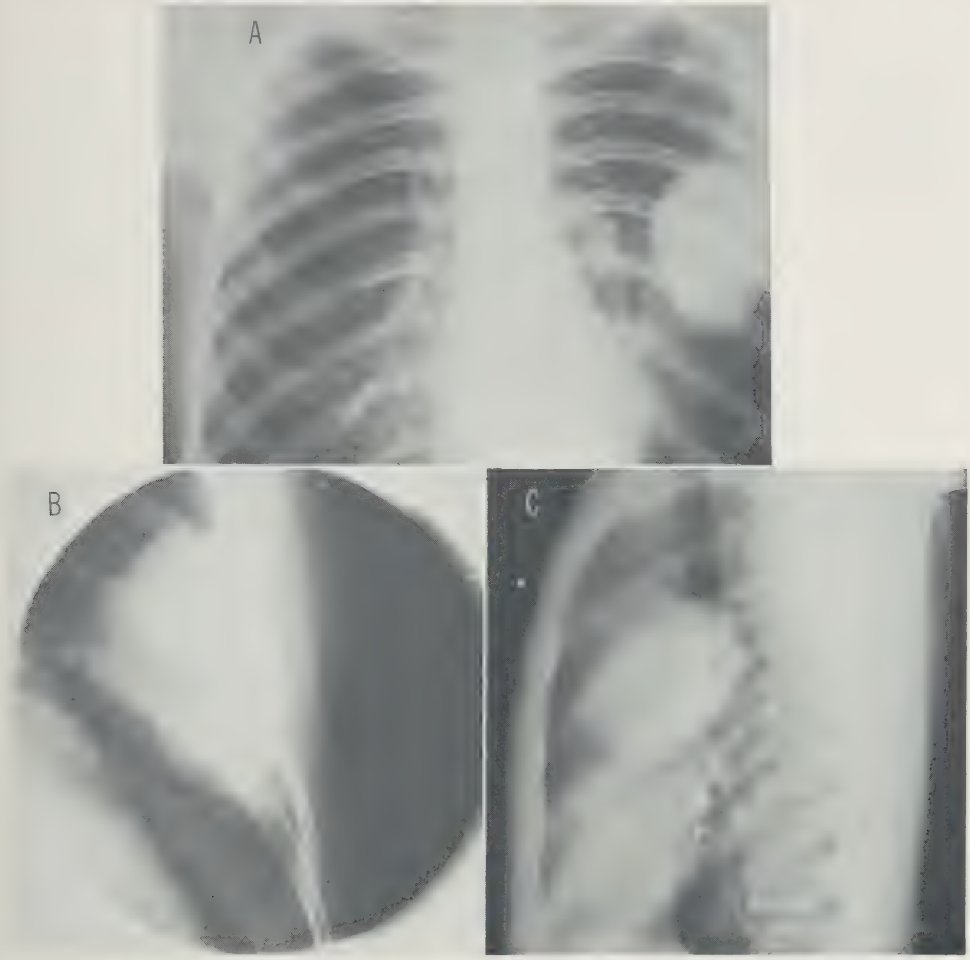

FIGURE 226.—Endothelioma of left pleura. Tumor masses sometimes showed up on radiographs of the chest made on other indications. Because many soldiers had been overseas for several years, it was possible for these masses to attain considerable size, in the absence of indications for chest X-ray, before they were detected. A. Postero-anterior view of chest showing large rounded mass in left hemithorax. B. Spot study of chest showing no erosion of ribs or other bony involvement. C. Lateral projection.

bore little resemblance clinically to patients observed in Puerto Rico with this disease. Marines from Wallis Island with filariasis, who were studied in Melbourne, had retroperitoneal and deep muscle abscesses, but no radiographic findings.

In dengue fever, as in Q fever, the only positive chest findings resembled those of atypical pneumonia. There was a fine, diffuse increase in markings throughout the lungs, but the changes were not pathognomonic.

Heart

Combat lesions.—Very few combat wounds of the heart were observed in hospitals in SWPA, where the circumstances of warfare made survival long enough to reach a medical installation equipped for definitive surgery even more unusual than it was in other theaters (p. 296). The occasional patient who was seen with a foreign body in the pericardium was evacuated to the Zone of Interior for definitive treatment. No kymographic studies for purposes of localization were done in SWPA, one reason being that there was only a single kymograph in the area, at the 42d General Hospital.

Noncombat lesions.—Since men with cardiac lesions were not accepted into the Armed Forces, only a few patients with such conditions were encountered. Rheumatic heart disease with myocardial involvement took a certain toll, and there was a relatively high incidence of myocardial infarction from coronary arterial disease, which in military service was apparently striking a younger age group.

If patients in forward hospitals were suspected of having some cardiac condition, they were evacuated to general hospitals for the routine studies proper in the circumstances. Evacuation, station, and general hospitals were all equipped with electrocardiographic apparatus, and this type of examination furnished more useful information than fluoroscopic or radiographic studies. Fluoroscopy was seldom employed in cardiac conditions. Radiographs were more useful, as well as easier to make, in view of the generally poor conditions for fluoroscopy (p. 607).

On one occasion, the 4th General Hospital injected an opaque medium into the heart to visualize the chambers, in order to distinguish between a congenital heart lesion and a small mediastinal tumor. Special equipment was not available for this type of examination, and improvised methods had to be used. In its annual report for 1943, this hospital requested that 70 percent Diodrast (iodopyracet) be included in the drug list of general hospitals, so that this technique (Robb-Sternberg) could be carried out. Major Reavis was opposed to this request. He could see no indication for visualization of the cardiac chambers in an oversea theater and recommended that patients who might need such a diagnostic measure (in the unlikely event that they were sent overseas) should be promptly evacuated to the mainland.

At the 42d General Hospital, a suspected mediastinal tumor turned out to be a tumor of the thymus (fig. 227).

Occasional instances of dextrocardia and situs inversus were observed. Coarctation of the aorta was not encountered, nor did any radiologist in SWPA report notching of the ribs.

Beriberi heart was seen in numerous prisoners of war. Lt. Col. Frank G. Drischel, MC, reported that while he was serving as radiologist with the 313th General Hospital, then part of a hospital center in Manila, large numbers of released prisoners were admitted for treatment of malnutrition, hypochromic anemia, and an excessive fluid retention. The most remarkable

FIGURE 227.—Tumor of thymus observed at 42d General Hospital, originally believed to be a mediastinal tumor. A. Posteroanterior view of chest showing accumulation of fluid in left hemithorax with apparent displacement of heart and mediastinum. A mediastinal mass is observed above the cardiac border on the right.

radiologic finding in this group was pericarditis with effusion, which was observed in numerous patients who also exhibited massive retention of fluid, though there was usually little in the pleura. They were able to be ambulatory, and those who were not too seriously malnourished made remarkably quick recoveries, sometimes within 24 hours, once they had sufficient protein in their diet.

Gastrointestinal Tract

Gastrointestinal complaints were extremely numerous in SWPA, and, as a result, gastrointestinal examinations were made in more than 90 percent of the hospitals that had X-ray equipment. The heaviest load was carried by general hospitals, but station hospitals and even evacuation hospitals also conducted these studies, though in many instances the radiologic officers—or the nonradiologic officers in charge of the service—were imperfectly trained to perform them or had no specialized training at all.

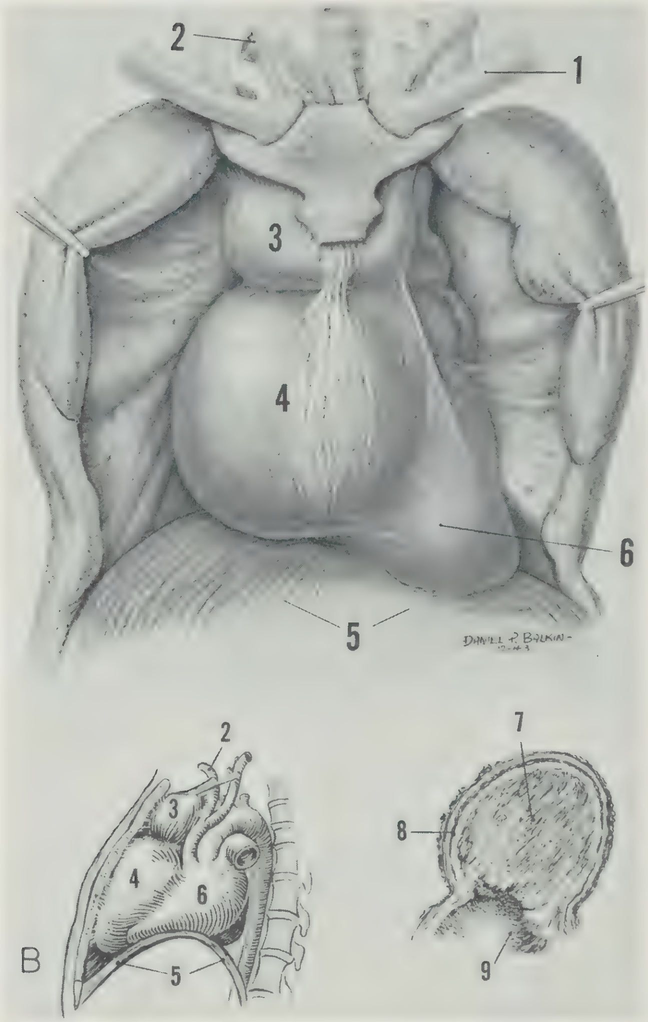

FIGURE 227.—Continued. B. Findings at post mortem examination: Top, relation of cystic neoplasm of thymus gland to heart and mediastinal structures, showing left clavicle (1), right innominate vein (2), tumor (3), cyst (4), diaphragm (5), and pericardium (6). Lower left, lateral aspect of chest showing tumor and cyst in relation to heart—right innominate vein (2), tumor (3), cyst (4), diaphragm (5), and pericardium (6). Lower right, sagittal sketch showing structural detail of solid portion of tumor and cyst—fibrous massive tissue (7), healthy thymus tissue (8), and villi lining (9).

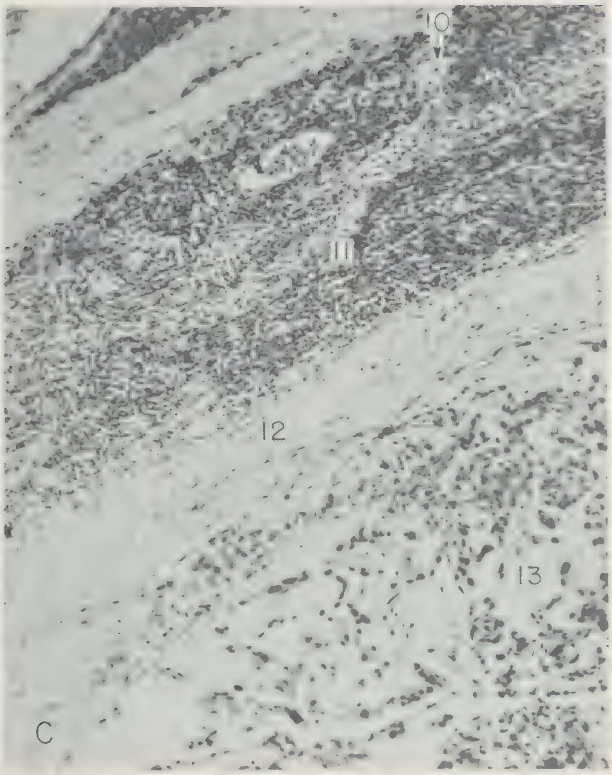

FIGURE 227.—Continued. C. Photomicrograph showing: Hassall's corpuscle (10), lymphoid tissue of thymus gland (11), compressed tumor tissue (12), and tumor tissue (13).

Gastrointestinal complaints always increased in number in advance of campaigns. Every effort was made to investigate the complaints, to be sure (p. 693) that no really ill man was sent into combat. On the other hand, the requests for these studies sometimes became impossibly heavy, particularly in hospitals that had only field radiologic equipment available. At one time, the radiologist of the 1st Evacuation Hospital had to ask the commanding officer to order that no patient be X-rayed until he had had a complete clinical study, including gastric analysis.

The distribution of complaints was interesting. They always increased, as just noted, before new campaigns. When the 17th Station Hospital was in Darwin, Australia, it provided medical service for an airbase, very few of whose personnel complained of digestive disturbances. When this hospital moved to Milne Bay, it was required to diagnose a large number of vague symptoms in members of the 32d Infantry Division stationed in Buna, in Marines who had been on Guadalcanal, and in Navy officers on LST's (popu-

FIGURE 228.—Cardiospasm, a condition observed only infrequently in troops in the Southwest Pacific Area.

larly known as Large Slow Targets). There was not a single positive X-ray in this composite group. It was concluded that their numerous complaints could be explained by the nervous strain on frontline troops, most of whose symptoms dated from periods of combat, and on the officers responsible for slowly moving boats. In the Air Force group, on the other hand, the strain of flights was compensated for by good diet, better living conditions, and long periods of rest.

A high percentage of gastric atony and visceroptosis was observed during the gastrointestinal studies. These findings were not associated with organic lesions, and they were noted particularly in men who had been in SWPA for a year or more. Cardiospasm was occasionally seen (fig. 228).

The incidence of peptic ulcers in all general hospitals in Australia was higher than it would be in a civilian population. The explanation might be that many station and other hospitals funneled such patients to general hospitals. Duodenal ulcer was diagnosed at the 4th General Hospital in about 15 percent of all gastrointestinal examinations. Outside of Australia, the incidence was lower. The 54th General Hospital found only 4 duodenal ulcers in more than 450 examinations. In a collected total of 1,386 examinations, there were 160 duodenal ulcers, 4 gastric ulcers (fig. 229), 2 gastric carcinomas, and 1 duodenal polyp.

FIGURE 229.—Gastric ulcer clinically benign, of type occasionally seen in the Southwest Pacific Area. Duodenal ulcers were seen more often and were, in fact, unexpectedly frequent.

While the 27th General Hospital was in New Guinea in 1945, 3 patients with paraduodenitis were observed in 1,000 gastrointestinal studies. Their symptoms were suggestive of peptic ulcer, but there was no sign of ulcer craters. Two of these patients, who developed mild jaundice, were found to be infected with trophozoites of *Entamoeba histolytica*. After standard treatment with emetine hydrochloride, carbasone, and chiniofon, their symptoms disappeared, and the X-ray picture returned to normal. Other patients with the same sequence were observed later; gastrointestinal symptoms appeared, and paraduodenitis was demonstrated radiographically before laboratory examinations became positive. The observations were regarded as significant because in civilian practice the X-ray picture would have been interpreted as presaging duodenal ulcer or gallbladder disease.

When the 12th Station Hospital was in Townsville, Australia, and was receiving casualties from the Buna-Gona Campaign, Major Morton observed a number of patients with hookworm. In this campaign, the U.S. troops had fought and lived—usually in the mud—with native litter bearers, and many of them had sustained massive parasitic infections (p. 633). In some instances of acute hookworm infection, the radiographic chest findings resembled those seen in trichinosis in the United States.

Certain gastrointestinal findings were most unusual. The duodenal cap and second portion of the duodenum, for instance, showed segmental spasm that resulted in such tight and such frequent churning that it could best be described as starlike. There was no evidence of ulceration. While the 17th Station Hospital was in New Guinea, Maj. Leonard S. Ellenbogen, MC, also

observed deformities of the duodenal bulb, sometimes erroneously diagnosed as duodenal ulcers, which were apparently associated with hookworm disease.

While the 4th General Hospital was at Melbourne, it received a number of patients with jaundice and hepatitis that were later found to be the result of the yellow fever vaccine used. In most of these cases, the jaundice was preceded, about 3 weeks on the average, by gastrointestinal symptoms for which radiologic studies were requested. The positive findings almost uniformly included pylorospasm, irritability of the duodenum, and edema of the duodenal mucosa, with no evidence of ulcer. Experience soon showed that patients with these radiographic findings were very likely to become jaundiced and develop hepatitis.

The so-called deficiency pattern in the small intestine was seldom observed, even in patients who were so malnourished that they obviously had vitamin deficiencies. Regional enteritis was occasionally observed, and the diagnosis of acute appendicitis sometimes had to be excluded. In one particularly striking case, observed at the 42d General Hospital, the followup (6-hour) film showed an extremely ragged, irregular, almost moth-eaten section of ileum, about 15 inches long. The patient was evacuated to the Zone of Interior after recovery from resection of the involved segment.

The number of barium enemas was considerably less than would have been required in a similarly large population in civilian hospitals. The majority were grossly negative. In 471 examinations at the 4th General Hospital, there were 5 instances of ulcerative colitis, 1 of polyposis, and 1 of carcinoma of the sigmoid. Apparently the colitis that occurred in SWPA was so mild, or was of such short duration, that radiographically demonstrable changes did not occur. A very low incidence of malignant disease would, of course, be expected in this age group.

The preparation of patients for gastrointestinal studies was generally standardized throughout the war, and, as far as was practical, the same principles and practices in use in civilian hospitals were used in Army hospitals. Food was withheld for 8 to 12 hours, regardless of the time at which the examination was done. As pointed out elsewhere (p. 607), fluoroscopy frequently had to be done at night or very early in the morning because of the heat and the lack of a totally lightproof examining room.

Biliary Tract

Gallbladder studies were done in hospitals at all echelons, but, again, general hospitals carried the heaviest load. At the 42d General Hospital, Brisbane, Australia, between September 1942 and October 1944, 316 examinations were made. On the whole, less than 10 percent were significant, and the incidence of gallstones was less than would be expected in a similar civilian population. The 4th General Hospital, Melbourne, Australia, made 212 studies between 10 April 1942 and 30 December 1943; they showed 27 poorly functioning or nonfunctioning gallbladders and 11 diseased gallbladders.

Practically all studies were made with tetraiodophenolphthalein, used by mouth and not by vein. This was the best preparation then available, but it was realized that it was toxic and that the results of the examination were not always reliable.[3] All patients were fed a fatty meal, and, when it was practical, an enema was given the morning of the examination.

Five cases of amebic liver abscess were reported by Major Morton, two in Australia and three in New Guinea. The first of these patients was thought to have regional ileitis, and he died a month after resection had been undertaken on that diagnosis. The correct diagnosis was not made until autopsy. The other patients all recovered after surgery, which the radiologist urged in each instance, supplemented by emetine therapy. These four patients were all members of the civilian Australian or U.S. merchant marine, and the pattern of illness in each instance was the same: tropical travel, irregular food not provided at any Army or other supervised mess, and close association with civilians. The first patient also fell into the same category; he had been on detached service in Darwin and was ill when he returned to Melbourne.

These patients were all referred for X-ray examination when they developed unexplained fever and slowly increasing hepatomegaly, without jaundice. Hepatic enlargement was unmistakable, both clinically and radiographically. When the abscess developed (fig. 230), the diaphragm was almost smooth until quite late in the disease, in contrast to the findings in gallbadder disease or perforated peptic ulcer.

The abscess in each of these five cases was in the right lobe of the liver, as it was in practically all cases reported in the literature. The explanation for the lateral preference is probably the difference in the blood supply of the two of the liver sides. One patient observed in Townsville apparently had a mass in the left upper quadrant, but when the abscess sinus track was followed back, the original lesion was found on the right side, though it had crowded the falciform ligament into the left compartment.

Genitourinary System

Incidence of disease.—The high incidence of urinary tract disease in SWPA is evident in the proportion of examinations requested of the genitourinary system. During one 6-month period, the 9th General Hospital performed 217 intravenous pyelograms in a total of 13,731 examinations for all causes (1.58 percent). The proportion was almost the same over a similar period at the 54th General Hospital, during which there were 185 intravenous pyelograms in a total of 12,044 examinations (1.53 percent).

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[3] Safer and more efficient preparations have been developed since the war. One of them, Telepaque (iodopanoic acid), has the property of leaving a residue in the intestinal tract, which, while it may somewhat obscure the gallbladder shadow, will definitely indicate that it has been taken, so that evidence of a nonfunctioning gallbladder can be accepted at face value. Telepaque would be a particularly useful preparation in military radiology for the malingerer who states that he has taken the medication when he has not (p. 557). Another useful postwar technique is the 5-day method of Salzman; the medication taken is expected to coat the gallstones and thus permit the visualization of many not evident by older techniques.

FIGURE 230.—Amebic infection. A. Amebic empyema in left chest. The fluid was sterile and no amebae were found. B. Liver abscess 2 months later. The correct diagnosis was not made until the abscess caused a marked elevation of the right diaphragm.

An occasional hospital, such as the 76th Station Hospital on Leyte, reported that more stones were observed in the ureters than in the kidneys. The 105th General Hospital reported an increase in calculi of 100 percent when the hospital left Australia and moved to Biak.

The figures cited do not include retrograde pyelograms, the number of which was much smaller. During the period just mentioned, the 54th General Hospital made only 54 such studies. Nor do the figures include other radiographic examinations for suspected urinary tract disease. Cystograms were not employed very often; their value is limited, and the information obtained from them does not go beyond calculi, cystitis, diverticula, and neoplasms. Flat plates of the abdomen, however, were frequently used for suspected urinary tract disease, since the information thus obtained also included other systems.

Calculi.—The incidence of renal calculi was high, much higher than would be found in a comparable civilian group in the United States. Many of the stones were causing no symptoms and were not detected even on radiographs; some observed at the 4th General Hospital, both in Australia and in New Guinea, were no larger than the head of a pin. Many calculi were found incidentally, when radiographic examination was undertaken to investigate pain in the back and flank. During one quarterly period, the report of the 9th General Hospital mentioned the passage, either spontaneously or with only slight cystoscopic manipulation, of 29 calculi, all of which had been diagnosed by X-ray. Over the same period there were 17 instances of typical renal colic in which the radiographs were negative and stones were not

passed. In none of these cases did stasis or obstruction appear to be a cause of the calculi, and most of the patients had not been on sulfonamide therapy.

The explanation of the high incidence of urinary calculi was however quite simple: Tropical acclimatization was accompanied by physiologic disturbances of the fluid and electrolyte balance. An individual with a predisposition to urinary calculi from other causes was more likely to form stones under conditions of military service in the tropics. Dehydration was also always a factor, and a large majority of the troops did not heed the instructions to drink water and take salt.

Other conditions.—Many soldiers complained of urinary frequency but had entirely negative radiographs. The more uncommon abnormalities were sometimes observed, such as horseshoe kidney, polycystic kidney, and ureterocele. An occasional perinephric abscess was encountered. Observations at the 4th General Hospital are typical of those at other hospitals in the same echelon of medical care: In 1,106 examinations of the urinary tract (including retrograde and intravenous pyelograms and flat plates of the abdomen), there were 60 instances of hydronephrosis, 52 ureteral calculi, 25 renal calculi, 7 calculi of the urinary bladder, 3 instances of tuberculosis, and 1 carcinoma of the bladder.

Intravenous pyelography.—Patients undergoing intravenous pyelography were usually forbidden fluids for 8 to 12 hours before the examination. They were given some laxative, usually castor oil, and, when it was feasible, enemas of plain water were given on the morning of the examination. Enemas were often completely impractical, and many intravenous pyelograms were done without standard preparation.

The contrast medium supplied by the Army in World War II was Diodrast, which was—and still is—an excellent preparation for this purpose. The conjunctival sensitivity test was used: A drop of the Diodrast was placed in the eye, and the examination was proceeded with, on the ground of absence of sensitivity to it, if there was no reddening of the conjunctiva within 5 minutes. The intradermal sensitivity test was also used; 1 cc. of Diodrast was injected, and if a large red wheal did not form within 5 minutes, it was assumed that this medium could safely be used.[4]

In all his hospital visits while he served as Acting Consultant in Radiology, Major Reavis took particular care to inquire into possible reactions after intravenous pyelography. An occasional minor reaction was reported to him, but there were no deaths and only one serious reaction, at the 42d General Hospital: This patient, immediately after the intravenous injection of 20 cc. of 50 percent Diodrast, became pulseless, cold, and clammy, and his blood pressure could not be obtained. He was apparently in deep shock. The head of the table was lowered at once, and adrenalin was given intravenously and

[4] Postwar studies by Pendergrass and his associates (4) indicated that neither of these tests is reliable. Their extensive studies and their recommendations for new techniques were published in the *American Journal of Roentgenology* in 1955.

subcutaneously. The response was immediate, and, after a period of observation, the patient was returned to his bed in excellent condition.

Female genital tract.—Examination of the female genital tract was seldom a radiologic responsibility in SWPA, with one exception: For a number of months before the invasion of the Philippines, Gen. Douglas MacArthur was in contact with guerrillas, who were supplied with electronic equipment, ammunition, medical supplies, and other items by submarine. On their return trips, these submarines brought back many evacuees, most of them women and children, and pelvimetry was sometimes indicated in pregnancy. At the 42d General Hospital, the Torpin-Thoms technique was employed with improvised apparatus. A backrest was constructed of plywood, so notched that the patient could be properly positioned, and an adjustable stand was made to hold the ends of a lead plate large enough to cover a 10- by 12-inch film. Perforations were drilled in the plate 1 cm. apart. When pelvimetry was necessary, the improvisation worked very well.

Spine

Fractures.—The most frequent acute condition of the spine for which X-ray examination was necessary was fractures caused by combat wounds and by traffic accidents. The most usual form of accidental injury was a compression fracture of the body or a linear pull of a transverse process. The whiplash type of injury had not yet been described and therefore furnished no problem for radiologists or for Disposition Boards.

Diseases.—Hypertrophic arthritis was not common. It was seldom observed in enlisted men, though officer personnel, particularly of the higher ranks, often showed early changes, usually beginning lipping and possibly slight narrowing of the interspaces. Marie-Strümpell disease was observed somewhat more frequently. Advanced disease was seldom seen; most radiographs simply showed early sclerosing changes in the sacroiliac joints. Both arthritis and Marie-Strümpell disease were usually seen in hospitals in which Disposition Boards were working on the evacuation of patients to the Zone of Interior.

Other conditions observed on radiographs of the spine included juvenile round back, which was frequent; tuberculosis; osteomyelitis after trauma; occasional tumors; and even such really rare conditions as actinomycosis of the chest wall (fig. 231) and brucellosis of the spine.

Low back pain.—The complaint of low back pain was responsible for the largest number of radiographs of the spine taken in all hospitals of the Southwest Pacific. The complaint was frequent early in the war, and its frequency increased as time passed. This might have been expected. Since backache is a relatively common complaint in civilians, it would naturally be a frequent complaint in military practice, and its frequency would naturally increase as the element of fatigue entered the picture and as men did heavy work to which they were unaccustomed. Also to be taken into account was the group of

FIGURE 231.—Sinus tracts of left chest wall, caused by actinomycosis. The tracts have been injected with an opaque medium.

malingerers, who realized that a spurious complaint of backache was difficult to classify as such without extensive diagnostic procedures.

During June and July 1944, the X-ray section of the 362d Station Hospital, Oro Bay, New Guinea, made 205 examinations of the vertebral column, 64.8 percent of which were of the lumbar and sacral regions; 84 percent of the radiographs of these regions showed nothing to account for the patient's complaints. Since a number of the positive radiographs were of patients who had sustained acute injuries, the proportion of patients with low back pain with insignificant or entirely negative radiographic findings is even less than these figures might at first suggest.

The majority of medical officers, however, were convinced of the validity of most complaints of backache. Radiologists at the 12th Station Hospital soon learned to recognize the combination of a negative radiograph of the lumbar spine, in spite of severe backache, and an abnormally large spleen and to interpret the findings as indicative of impending malaria. The usual clinical sequence was a headache the first day, severe backache the second, and a chill the third. The diagnosis, the chief of the radiology section of the 12th Station Hospital pointed out, did not require too much astuteness, for in the

early period in New Guinea, before Atabrine (quinacrine hydrochloride) came into general use, a large proportion of men who were ill might be expected to have malaria.

At the 17th Station Hospital in New Guinea, an attempt to develop criteria for the diagnosis of malaria by the degree of enlargement of the spleen was not successful.

It was Major Morton's custom, when a radiograph of the spine was negative, to ask a man who had been in the tropics for some time to bend while he palpated the lumbar spine. If he could feel little or no motion, he considered a tentative diagnosis of ankylosing spondylolisthesis justified and proceeded to a careful study of the sacroiliac joints to determine the earliest changes in them, or possibly in the facets, in accordance with previous observations in the Middle East. Whether the heat or the living conditions or dietary factors explained the increased incidence of this condition in the tropics, no one was able to say, but it was a very general observation, as Major Reavis verified on his tours to various hospitals while he was Acting Consultant in Radiology. Major Morton commented that while he saw a case a day in Townsville, he had never seen the condition with such frequency in more temperate climates. He also considered it of interest, and possible significance, that the joints involved in this disease are those in the depths of the body and therefore with the highest body temperatures.

Errors of interpretation.—It was a common error for untrained radiologists to interpret inconsequential anatomic variations or congenital anomalies, which were fairly frequent, as serious pathologic processes. Capt. Daniel L. Doherty, Jr., MC, pointed out a number of such errors at a medical seminar at the 362d Station Hospital, Oro Bay, New Guinea, 14 August 1944:

1. Apophyseal centers of the transverse process of the last lumbar vertebra are occasionally mistaken for fractures, especially if the center is unilateral, as it frequently is. Closer study will show the adjacent surfaces of the supposed fracture to be smooth and rounded and not sharp and irregular.

2. Some of these structures are seen on the articulating facets of the lumbar vertebrae. Fractures of the tips of the articulating processes are almost impossible to produce, and these apophyses are seen to be smooth and rounded in their adjacent surfaces. The second and third centers are most commonly involved in such processes and are generally on the inferior facets.

3. Asymmetry of the planes of the articulating facets on both sides is very common in the lower lumbar region and is not significant unless it is associated with actual malalignment of the spine.

4. Spina bifida involving the fifth lumbar vertebra and first sacral segment is quite common and does not contribute to back pain.

5. Similarly, unilateral or bilateral sacralization of the last lumbar vertebra is extremely common, but if it is complete and stable, it is not a cause of pain.

6. The plane of articulation of the sacroiliac joints varies considerably. Practically all inflammatory processes affecting these joints are of low grade, and bone repair is a concomitant process with bone destruction. The result is a sclerotic zone at the periphery of the destructive area.

7. Spur-like projections at the inferior margins of the sacroiliac joints are normal variations in their articulation and are not of significance.

Spondylolisthesis.—Captain Meschan, at the 4th General Hospital, reviewed 1,131 radiographs of the lumbosacral spine made over a period of 20 months on patients with backache (*5*). The abnormalities most frequently observed were Marie-Strümpell disease and congenital anomalies, including spondylolisthesis. Of 51 patients with defects of the pars interarticularis, 41 were found to have spondylolisthesis.

Special techniques for diagnosing this condition were developed at this hospital. Oblique projections brought out the pars articularis particularly well, which was important, for this structure was often the location of a congenital unilateral or bilateral defect that was sometimes responsible for back pain. When spondylolisthesis was suspected, the radiographs were taken in the upright lateral position, in both hyperextension and hyperflexion, with the ray centered over the fifth lumbar vertebra. With this technique, it was possible to demonstrate any increased mobility of the suspected vertebra, as well as its relation to adjacent vertebrae.

Using a mensuration technique, Captain Meschan concluded that spondylolisthesis can be recognized by the position of the apex of an angle formed as follows:

1. A line is drawn from the posterior lower lip of the vertebral body just above the involved vertebral body to the posterior upper lip of the vertebral body below it.
2. A line is drawn between the posterior lower and upper lips of the involved vertebral body.
3. If these lines are parallel, as they seldom are in spondylolisthesis, the linear distance between them is measured. A distance of more than 3 mm. is regarded as abnormal. When the distance between the parallel lines is 4 mm. or more, the position of the apex of the angle is always above the suspected vertebral body in spondylolisthesis.
4. If these two lines are not parallel, they are extended until they meet and form a measurable angle, which is measured with a protractor. Angles up to 10° are considered slight, up to 20° moderate, and above 20° severe.

Captain Meschan also used the mensuration technique to determine the degree of a slipped vertebral body. Lateral roentgenograms of the lumbosacral region were taken first with the patient recumbent and then in the neutral position and in hyperflexion and hyperextension. In 7 of the 41 cases of spondylolisthesis in this series, the displaced body was not stable.

Captain Meschan objected to the current general practice of classifying spondylolisthesis as a congenital anomaly. He considered the evidence at hand sufficient to show that trauma may widen the defect, trigger the symptoms, and initiate the displacement of the vertebral body.

When he made his first report, the 4th General Hospital was operating in a rear echelon in SWPA. After it had moved to forward areas, first to Finschhafen and then to Manila, he made a second study of this condition, this time examining 520 radiographs of the lumbar spine taken over a 6-month period (*6*).

The stability studies in the second series convinced Captain Meschan that the later figures were more representative of the true incidence of spondylolisthesis in military circumstances than were those in the first study. In the

first, defects in the pars interarticularis were observed in 5 percent of the radiographs; in the second, they were observed in 11.7 percent. In the first series, the incidence of spondylolisthesis was 3.6 percent; in the second, it was 6.5 percent. In the first series, the incidence of instability was 35 percent; in the second, it was 50 percent.

It was Captain Meschan's conclusion that the humid tropical climate in which the men examined in his second study had been working had had an aggravating effect on their condition; that half of all slipped vertebral bodies are unstable under circumstances of stress; and that trauma, stresses, and strains all play roles of particular significance in the etiology of spondylolisthesis.

The memorandum that Major Reavis prepared for distribution after he realized the high incidence of spondylolisthesis in SWPA (p. 571) contained the following basic information:

1. Spondylolisthesis is a pathologic process in the vertebral column, most often in the lower lumbar region, which is characterized by a cartilaginous defect at the laminopedicular junction, accompanied by a forward subluxation of the anterior portion of the vertebra, that is, the vertebral body, pedicles, and superior articular facets. The inferior articular facets, a portion of the laminae, and the spinous processes remain in the original position.

2. The condition is believed to be congenital. It may be unilateral or bilateral.

3. Diagnosis is made chiefly by radiographic demonstration of the lesion. Routine anteroposterior and lateral projections are usually adequate and are readily interpreted. Oblique projections are valuable, but they are difficult to interpret and should be left to the highly trained radiologists. The degree of subluxation is the index to the degree of the pathologic process. If the forward vertebral displacement is one-fourth the anteroposterior diameter of the vertebral body, it is first degree. If the displacement is one-half, the condition is second degree, and so on.

4. Lateral projections taken with the Army field unit are often lacking in bony detail. The anterior margin of the promontory of the sacrum and the posterior margin of the body of the first sacral segment are often poorly delineated, and errors in determination of alignment are therefore common. Both the anterior and posterior margins of the vertebral bodies in the lumbosacral area must be closely studied from this standpoint. Repetition of the examination with the central ray projected through the suspected segment will often show the alignment to be within limits of normal.

5. Occasionally, a defect may be observed in the isthmus without evidence of subluxation. In this condition, designated as preslipped spondylolisthesis, the defect is usually unilateral. The patient, however, must be assumed to be a candidate for vertebral subluxation, since an isthmus with a defect is frequently unable to supply the strong support necessary between the superior and inferior articular facets.

6. The use of the term spondylolisthesis for the defect just described is not desirable. This nomenclature is applicable to any defect in the neural arch, in which defects are not uncommon, especially those caused by failure of fusion of a lamina at the base of the spinous process. Such a defect, therefore, does not represent a preslipped spondylolisthesis. This term is applicable only when true alignment has been preserved and an isthmic defect is demonstrated.

7. The diagnosis of spondylolisthesis, it must be emphasized again, can be made only by visualization of the defect in the isthmus plus forward subluxation of the vertebral body.

Herniation of the nucleus pulposus.—Men who complained of low back pain accompanied by radiation of the pain to the legs or by neurologic findings were usually returned to the Zone of Interior (7).

Plain films of the lumbar spine were of little value in suspected ruptures of the lumbar disk, though occasionally, in longstanding cases, narrowing of the intervertebral space might be noted. If the patients persisted in their complaints, myelography (fig. 232) was considered indicated.

Myelography was done extensively in general hospitals equipped with tilt tables. It was also done in many hospitals that did not have these tables but that improvised techniques of tilting the patient. Hospitals which had neither tilt tables nor spot film devices were unable to make myelograms.

Lipiodol was in short supply in SWPA and Pantopaque (ethyl iodophenylundecylate) was not available at all. Both air and oxygen, however, proved satisfactory for myelography, oxygen being preferred because it absorbed more rapidly. Interpretation of the myelograms was more difficult than when an oily contrast medium was used, but many radiologists became quite adept at it. The characteristic finding was a unilateral or bilateral thumbprint defect in the column of air or opaque substance at the level of the intervertebral space. If compression of the spinal root had occurred, the opaque medium would not pass into it.

Ruptured disk (herniated nucleus pulposus) was by no means uncommon. In 134 myelograms made at the 4th General Hospital in Melbourne (124 with oxygen and 10 with Lipiodol), between 10 April 1942 and 12 October 1943, 30 were positive for this condition.

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FIGURE 232.—Herniated nucleus pulposus. A. Air myelogram showing rupture at L5. B. Air myelogram showing rupture at L5. Note characteristic hourglass defect. C. Normal air myelogram, showing column of air extending from lower margin of L3 downward into sacral canal. There is no impingement on the column. D. Oil (Lipiodol) myelogram showing symmetrical filling defect characteristic of large ruptured disk at L4. E. Same, showing rupture at L5.

CHAPTER XXXII

Radiation Therapy

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GENERAL CONSIDERATIONS

The prevalence in SWPA (Southwest Pacific Area) of numerous dermatologic conditions amenable to radiation therapy made it even more logical to employ this form of therapy there than in the European (p. 485) and other theaters. The basic reason for its use was always the same, that by the employment of this method in local installations, many men could be treated on an ambulatory basis and kept on duty who otherwise would have had to be evacuated to rear areas—a far more difficult undertaking in SWPA than in the Mediterranean and European theaters—or who might have been permanently lost to duty in the area. If hospitalization was required, the stay days were shortened, sometimes by as much as 2 months or more.

There were, of course, numerous arguments against providing such therapy: Paucity of proper equipment, climatic conditions that led to operational difficulties, a scarcity of qualified radiotherapists,[1] and the impossibility of observing the end results of treatment. A number of qualified radiotherapists hesitated to use this modality for the latter reason, and there was justification in their objection: Many patients were sent to duty in forward areas before any results at all of treatment could be observed.

Whether or not therapy was administered in any given hospital depended upon the location of the unit, the special need for this type of treatment, and, perhaps most important of all, the desire of the responsible radiologist. Some therapy was administered by officers who were not qualified to give it. Some qualified radiotherapists who did not administer it might, perhaps, have overcome the obstacles in the way and provided it. On the whole, however, in spite of the difficulties and actual hardships imposed by the climatic and other local conditions, probably almost all who needed radiation therapy received it, and in most instances it was given competently.

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[1] In view of the small number of radiologists who were qualified as therapists in SWPA, it was ironic that it was one of the few who were certified who was queried by an inspecting officer as to who had authorized him to give X-ray therapy. The radiologist had just completed the treatment of a number of patients with dermatitis at the request of the staff dermatologist. The radiotherapist explained to the inspecting officer that he was a diplomate of the American Board of Radiology, was certified in radiation therapy, had calibrated his machine, and had given the then conventional one-quarter skin erythema dose for athlete's foot and similar conditions. The investigation ended at that point, with no further questions or answers on either side.

CONSULTANT SUPERVISION AND RECOMMENDATIONS

Had an efficient consultant system been in effect in SWPA, a great deal of effort and confusion would have been avoided in the field of radiation therapy, and the overall results would probably have been better. Such a system was never set up. On the contrary, as pointed out elsewhere, there was no overall plan for either diagnostic or therapeutic radiation service in SWPA.

When Maj. Charles W. Reavis, MC, was Acting Consultant in Radiology, he paid particular attention to therapeutic radiation in his visits to all hospitals with X-ray equipment. He found that practically all qualified radiologists, including certified radiologists, were doing some amount of superficial therapy. He also found that some men without previous training or experience in this highly technical field were also attempting to do it. He always recommended that therapy be discontinued in the latter hospitals.

In April 1944, a large general hospital in Finschhafen, New Guinea, requisitioned a 220-kv. therapy machine. Major Reavis recommended that the requisition should not be filled for several reasons: The bases were then being moved away from New Guinea rather rapidly, and the installation of such a machine would be relatively permanent. There would probably not be enough need for therapy in this particular area to justify the installation of a machine of this type. Finally, it was doubtful that the supply of current would be adequate for such a heavy machine. Major Reavis thought that a 140-kv. machine would be ample for the purposes and recommended that two of these be bought for use in advanced bases.

In his general recommendations for the establishment of a consultant system in SWPA, Major Reavis included certain specific recommendations concerning X-ray therapy:

1. Each base consultant should set up and maintain one or more X-ray units as necessary for therapy. They should be placed in such hospitals as the consultant selected.

2. These machines should be used only for therapy.

3. The hospital radiologist should personally supervise all treatments.

4. Unless, as recommended, base consultants were appointed, X-ray therapy should be permitted only in specified hospitals. Major Reavis' report of his survey of SWPA in 1944 (p. 570) indicated in what hospitals therapy should be administered by the radiologists in charge.

5. If a patient received radiation therapy in an advanced base and then was evacuated to the rear, information concerning the dosage and other details of treatment should accompany him.

6. It was desirable that X-ray therapy be administered in advanced bases, but essential that it be given only by radiologists qualified to give it. Since one or more qualified radiologists were then serving in every base area, there would be no hardship in setting up therapy centers in each base rather than permitting therapy to be administered promiscuously.

EARLY PROVISIONS FOR THERAPY

Until U.S. hospitals were able to provide superficial radiation therapy for their patients, the need for it was met by arrangements made with Australian hospitals. In Sydney, personnel from the 118th General Hospital were assigned for this duty to the Royal Prince Alfred Hospital. The only difficulty was that the two hospitals were 35 miles apart, and transportation problems often arose. By the middle of 1943, the U.S. hospital had its own fully equipped therapy room.

Similarly, in Melbourne, the 4th General Hospital was able to arrange for treatment of its patients in Dr. Rutherford Kaye Scott's Tumor Clinic at the Royal Melbourne Hospital. Some treatments were given at the 105th General Hospital in Gatton, Australia, by Capt. (later Col.) Donald P. Ham, MC.

EQUIPMENT

The Army field X-ray unit, which was the basic equipment of every X-ray section in SWPA, carried almost the entire load of superficial radiation therapy during the war. This unit, which was chiefly used for diagnosis, had many advantages. It could be used either in the field, where it was activated by the gasoline-driven field generator, or in a fixed installation, with activation from a regular source of power. It was small, compact, and self-rectified. As already pointed out (p. 603), it performed admirably under many trying conditions.

As a therapeutic instrument, the field unit was entirely satisfactory, but when it was operated at 100 kv., breakdowns were frequent. All over SWPA, radiologists complained of puncturing of cables and burning out of tube filaments, as the result of sudden surges in the line. These difficulties occurred whenever heat, humidity, and irregularities of current were encountered. The radiologist at the 17th Station Hospital, Milne Bay, New Guinea, commented that their field unit was run so steadily when it was used for therapy that it was always hot and dry, and mold was therefore never a problem, but cable breakdowns presented constant problems.

On 23 January 1943, the 42d General Hospital, Brisbane, Australia, had three cable breakdowns in 24 hours; treatments could not be resumed for 2 months. At the 35th General Hospital, so many patients with skin diseases were observed that the dermatologist recommended that radiation therapy be instituted. A field unit was therefore checked out of Medical Supply, but when three cable failures occurred while the first two patients were being treated, the idea was abandoned. Many other units also gave up the idea of X-ray therapy for the same reason and conserved their field units for more important diagnostic purposes.

At the 171st Station Hospital, Port Moresby, New Guinea, Capt. Robert Gross, MC, adopted a fractionation technique to minimize cable breakdowns. He rested the machine for 15 seconds after each 15-second exposure, so that a minute of therapy actually took 1¾ minutes.

Calibration of Machines

One reason why radiation therapy was not more generally used in SWPA was the necessity of calibrating the machines and the lack of Victoreen r-meters for this purpose.

For a time, a Victoreen r-meter was kept at the 118th General Hospital and another was kept at the 42d General Hospital. There was also one at Base 3, in Brisbane, Australia. One of Major Reavis' recommendations was that this meter should be retained at Base 3 and should not be moved to New Guinea or any other island, where humidity would ultimately destroy its accuracy. He also recommended that, while it might be farmed out on request, it should be used only by personnel who understood how to use it. His idea was that the base radiologic consultant should be responsible for it and for the calibration of all machines used for therapy. No base consultants were ever appointed, but as long as Major Reavis served as Acting Consultant in Radiology, this instrument was not sent to any hospital without his permission. The arrangement was entirely personal, based on the cordial relations between him and medical supply personnel, who phoned for his approval whenever a request for the instrument was received.

The wisdom of this recommendation was apparent from a number of experiences. In Townsville, Australia, because of the extreme humidity, the meter had to be dried in the oven before it could be used with any degree of accuracy. When it was requested for use in Manila, it was received in inoperable condition. Repairs could not be made locally, and the meter had to be returned to the Zone of Interior for them.

A number of radiologists in SWPA, unable to obtain the use of a Victoreen r-meter to calibrate their machines, found that the calibrations stated by the manufacturer worked within 10 percent for superficial therapy, which was a real tribute to the excellence of the Picker field unit. This plan was employed in Manila, where, as just noted, the Victoreen r-meter did not function. The base surgeon in Manila had requested the Surgeon, SOS (Services of Supply), SWPA, to have a number of machines calibrated for superficial therapy, and the attempt, which proved futile because the r-meter was inoperable, was made in April 1945, by 1st Lt. Frederick W. Shultz, MAC. Maj. (later Col.) John C. Ajac, MC, at the 2d Station Hospital, Nadzab, New Guinea, calibrated his machine by using the erythema dose.

Captain Gross, at the 171st Station Hospital, had anticipated the need for therapy in advanced areas and had had his two field units calibrated by Dr. C. E. Eddy, a physicist, in charge of the Commonwealth X-Ray and Radium Laboratory, Melbourne, while the hospital was still in Australia. The machines had gasoline field generators, and it was thought that the 20-percent variation from the output listed by the manufacturer for 100 kv. and 4 ma. was undoubtedly the result of variations in the source of power (table 14).

TABLE 14.—*Data on calibration of Picker field units, 171st Station Hospital, Melbourne*

Filter	r/min./air [1]			H.V.L. [2] mm. aluminum
	10 inch	12 inch	16 inch	
	Measured Calibrations			
Inherent	93	65	36.9	1.2
1 mm. aluminum	48.2	35.5	19.4	2.1
2 mm. aluminum	34.2	23.8	13.7	2.4
3 mm. aluminum	24.2	16.8	9.6	3.0
	Manufacturer's Calibrations			
Inherent	68	48	26	1.25
1 mm. aluminum	37	26	15	2
2 mm. aluminum	26	18	11	2.5
3 mm. aluminum	20	14	8	3

[1] Roentgen per min. per air dose.
[2] Half-value layer.

Protection of Personnel

Maj. (later Lt. Col.) Ernest W. Egbert, MC, estimated personnel exposure in a fixed unit in the Zone of Interior. Photographic film used to test stray radiation showed no darkening when it was exposed in the operator's position during a week of treatments. Measurements made with a quartz string microelectrometer revealed monitoring doses of 0.003 r at the point representing the operator's position when patients were being treated with 100 r with a 3-mm. aluminum filter. When the same dose was given unfiltered, there was a scatter of 0.001 r for each 100 r delivered to the patient. It was estimated that 100 such treatments could be given before the operator would receive a tolerance dose of 0.1 roentgen. Cumulative effects were not taken into consideration.

The whole subject of protection has been discussed in detail elsewhere (p. 578). The lack of it in many small X-ray sections was a potent argument against their employment of radiation therapy.

CLINICAL CONSIDERATIONS

Dermatologic Conditions

The most common indications for superficial radiation therapy were such skin conditions as eczematoid dermatitis, epidermophytosis, furunculosis,

FIGURE 233.—Dermatologic conditions frequently treated by radiation in Southwest Pacific Area, with generally satisfactory results. A. Epidermophytosis with secondary pyogenic infection. B. Epidermophytosis with secondary eczematoid dermatitis. C. Eczematoid dermatitis of 7 years' duration, aggravated by tropical climate.

pyoderma, folliculitis, lichen simplex, lichen planus, and hyperhidrosis (figs. 233 and 234). The differentiation between true lichen planus and the lichen planuslike eruption that sometimes follows Atabrine (quinacrine hydrochloride) therapy was recognized after only a short experience but was not generally discussed. It was obviously better to risk the reaction—which sometimes required evacuation of the soldier—than to risk malaria because this simple preventive measure was omitted.

So-called jungle rot was soon found to be many conditions in addition to the fungus infection it was originally thought to be. As a matter of fact,

FIGURE 234.—Lichen planus observed in New Guinea and treated by radiation.

true fungus infections were considered, by many dermatologists and radiologists, to be extremely uncommon. The majority of cases of jungle rot were uncomplicated eczematoid dermatitis, which was readily controlled by several X-ray exposures, though in the hot, humid climate of northern Australia, New Guinea, and the Philippines, recurrences were frequent. When weather conditions changed and the temperature fell, jungle rot was less of a problem. Hot, moist weather invariably prolonged it.

The question was sometimes raised whether, in view of the large proportion of recurrences, it would not be simpler to evacuate the affected soldiers at once. The justification for radiation therapy was the high percentage of prompt good results, the fact that many times recurrences did not occur for several months, and the further fact that many times the good results were permanent.

Casualties returned from Munda and Bougainville often had wounds filled with "jungle slime," which were red and moist and which looked wilted at the edges. These were *Proteus* infections, and radiation therapy, used tentatively, proved futile.

Pyoderma and otitis externa were of almost epidemic proportions in the 171st Station Hospital at Port Moresby during 1942 and 1943. Both were resistant to the usual remedies, but both responded well, and often dramatically, to four or five X-ray treatments.

Captain Gross treated about 200 patients with pyoderma, calibrating his machine according to information given by the manufacturer in the brochure that accompanied it. This machine permitted 100 kv. with a filter of 1 mm. of aluminum. The lesions were treated with air doses of 100 r at distances of 20 to 30 cm. at intervals of 3 to 5 days. No cones or collimators were available, and in all small lesions, lead or leaded rubber had to be used for blocking off the field.

In otitis externa, the lesions appeared on the external ear and crept along the canal, sometimes involving the drum. X-ray therapy gave the only really satisfactory results. The established dosage schedule was 100 r, with 1-mm. aluminum filter, at biweekly intervals.

Aerotitis was also a very common complaint. This process was secondary to lymphoid hyperplasia in and about the eustachian tubes. The response to radiation therapy was quick because of the exquisite sensitivity of lymphoid tissue to this modality. Aerotitis was chiefly observed in flying personnel.

Other Conditions

Painful tenosynovitis and bursitis were not observed as often as in civilian practice. X-ray treatments usually gave relief within 24 hours.

As in the European theater (p. 485), plantar warts constituted a large part of the therapeutic load (fig. 235). The dose was from 800 to 1,000 r, applied in a well circumscribed area, and followed by 10 to 14 days of rest. This technique was necessary because the rapid movement of personnel did not permit standard fractionation techniques.

Bromhidrosis was a distressing condition to both the patient himself and his associates in closely packed barracks. A large series of cases was treated at the 42d General Hospital, with prompt alleviation of the condition usually being secured with one or two treatments of 100 r in air.

Only two patients with gas gangrene were officially reported in SWPA. One, observed at the 168th Evacuation Hospital in New Guinea, responded promptly to treatment with the field unit. The other, a prisoner captured at Port Moresby, in September 1942, suffered a gunshot wound of the thigh. The diagnosis of clostridial myositis was confirmed by X-ray. The patient did not respond to therapy and died without regaining consciousness. This episode occurred during a critical period of the war, when the Japanese were

FIGURE 235.—Large plantar wart, about 1½ cm. in diameter, after treatment by radiation and surgical removal of central area. Note granulating tissue in base.

slipping across the Owen Stanley Range, and the radiologists had the double motive of treating the prisoner for humanitarian reasons and trying to save his life so that he could be questioned by Intelligence.

CASELOAD

The caseload varied widely with the location of the hospital and the period of its operation. The December 1944 quarterly report of the 13th General Hospital at Finschhafen showed 76 patients treated, 32 for eczematoid dermatitis; 10 for plantar warts; 9 for herpes simplex; 5 for acne; 3 for lichen planus; 3 for folliculosis; and the remainder for dermatophytosis, paronychia, pruritus, and sycosis barbae. For the same period (October-December 1944), the 165th Station Hospital in Dulag, Leyte, averaged 100 treatments a month, and the 248th General Hospital in Luzon, over a later 3-month period, gave 640 treatments to 92 patients.

At the 42d General Hospital, there was much greater therapeutic activity. Because this hospital had a deep therapy machine, it received referrals from the whole Southwest Pacific Area and also cared for Navy personnel from Mobile Hospital No. 9, which was also situated in Brisbane. During the 2-year period ending in October 1944, a total of 7,607 treatments were given, the largest number in May 1944, when 781 were given. In the January-March 1944 period, the average daily caseload was 47 patients.

The work fell off considerably when climate conditions improved. At the 54th General Hospital, while it was occupying the buildings of the Do-Ai Hospital in Tokyo late in 1945, treatments averaged only six per month.

RECORDS

The 42d General Hospital was able to secure form MD 55 K–3 to record the X-ray treatments given, but most hospitals were unable to obtain it. Such records of therapy as were kept, therefore, were maintained by the radiologists who administered the treatment.

The 42d General Hospital also devised its own forms on which the area of involvement could be delineated for the record.

DEEP RADIATION THERAPY

Only a limited amount of deep X-ray therapy was administered in SWPA, for two reasons. The first was the limited number of machines available for this type of radiation treatment. The second was the Medical Department policy, consistent in all theaters, that patients with malignant disease should be returned to the Zone of Interior for treatment. Deep X-ray therapy was used to make the patients transportable if that indication for treatment existed. In some instances, therapy was begun while the patients were awaiting transportation, and, if the response seemed good, they might be held until the course was completed. It was not the policy, however, to provide definitive treatment for malignant disease in SWPA.

Equipment.—Machines for deep X-ray therapy were available at the 42d General Hospital in Brisbane and at the 118th General Hospital in Sydney. In November 1943, a 200-kv. General Electric Maximar unit was installed at the 42d General Hospital, with a self-contained tube head. The head had no motor to move it up and down, and, since it was quite heavy, its manual operation was rather difficult.

The machine was housed in a specially constructed 15- by 15-foot concrete building, with walls and ceiling nearly a foot thick. There was a large sliding lead door between the therapy room and the control booth, and a leaded glass window permitted observation of the patient during treatment.

A Victoreen ionization chamber (ionometer) in the cone recorded the integrated dose on the controls. A Victoreen r-meter was kept in the section for

calibration of the radiation output, and constant monitoring of the dose being delivered was thus possible.

Indications.—The conditions treated with this unit included leukemia; bone tumors; brain tumors; multiple myeloma; carcinoma of the lung; tumors of the testis and lymphomas, which were the most common variety of malignant disease in the military age group (p. 204); and basal and squamous cell carcinoma of the skin.

A Polynesian with a connective tissue sarcoma was treated at the 42d General Hospital with 5,000 r, which it was thought would give him at least as good a chance of survival as surgery. With amputation, the patient had argued, he would be a beggar or worse if he lived until after the war.

Radiologists at the 4th General Hospital while it was in Melbourne gained a great deal from their contacts with Dr. Rutherford Kaye Scott at the weekly night conferences he conducted for his residents. Particularly impressive were the results obtained by his unique method of treating cancer with radon in flexible gold needles. It was the most successful radiation therapy they had ever seen.

OTHER MODALITIES

Except for the deep X-ray therapy just described, superficial radiation therapy was the only modality used in this field in SWPA. Radium was not supplied to the hospitals in the area, and none was captured from the Japanese. Isotopes were only beginning to be used and never reached the Pacific. Major Reavis, when he was in charge of radiology at the 42d General Hospital, planned to use phosphorus 32 in two cases of blood dyscrasia, in collaboration with Dr. A. G. S. Cooper at the Brisbane General Hospital, but the material could not be procured when it was needed.

CHAPTER XXXIII

Special Experiences[1]

Vernon L. Bolton, M.D., Donald B. Fletcher, M.D., Horace D. Gray, M.D., Ralph C. Moore, M.D., Joseph L. Morton, M.D., Charles W. Reavis, M.D., Walter J. Stork, M.D., Frederick W. Van Buskirk, M.D., Harold A. Vinson, M.D., and *Egon G. Wissing, M.D.*

FIELD HOSPITALS

1st Field Hospital

The 1st Field Hospital, like all hospitals in this category, was divided into three platoons, each of which was equipped to care for a maximum of 100 patients but which could care for 125. When the three platoons operated as a unit, the hospital could function as an evacuation or a station hospital. In either of these roles, it was supposed to handle 400 patients. At times, however, the census reached 600 to 650.

Each platoon had its own portable field X-ray unit and electric generator, and each had its own X-ray technicians. All the technicians were graduates of the Army school for technicians and were well qualified. When they were not engaged in radiologic duties, they acted as litter bearers, of whom there was always a shortage.

When the 1st Field Hospital functioned as a forward hospital, its radiologic work consisted mostly of fractures and foreign bodies. When it functioned as a station hospital, it did all kinds of X-ray work, including gastrointestinal examinations.

When the 1st Field Hospital arrived in Australia in 1942, it located in Rockhampton and functioned as a station hospital. Although in this capacity it accepted all types of patients, it had no radiologist up to December 1942.

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[1] The activities of departments of radiology were so closely integrated with the activities of the hospitals in which they served that the simplest way to describe the work of the departments is to relate the general or special experiences of several hospitals in the various echelons of medical care.

The radiologic experiences of all the hospitals that operated in SWPA (Southwest Pacific Area) were remarkably similar in respect to environmental difficulties, equipment and improvisations, power supply, and most other details. All such matters, therefore, to avoid duplication, have been deleted from these accounts and are discussed generally or, when necessary, specifically under the appropriate headings. The following histories are in no sense complete unit histories. For the most part, the accounts are merely experiences selected to illustrate the work of radiologic departments in SWPA and the circumstances under which the work was done.—C. W. R.

Medical officers read the radiographs which they had requested. Fluoroscopic examinations were not done, but an occasional orthopedic surgeon used this method to reduce a fracture.

In December 1942, Col. Harold A. Vinson, MC, was assigned as radiologist and served administratively as commanding officer of one of the three platoons. In January 1943, when the commanding officer was relieved for medical reasons, he assumed command of the hospital.

On 1 January 1943, the 1st Field Hospital moved to Milne Bay, where the bomb known as the Daisy Cutter was first encountered. Many of these bombs landed a short distance from the hospital, in a nearby concentration of Australian troops.

At Milne Bay, the hospital acted as an evacuation hospital. Casualties were accepted as they came. Such emergency surgery as was necessary was done, and transportable patients were sent back to Australia.

From Milne Bay, the hospital was transferred to Finschhafen, where it served as a station hospital for almost a year. The site selected was near the water, and only a short distance away from an anchorage for supply-type Liberty ships. As a result, dive bombers frequently flew over the hospital to drop their bombs on this area.

For the first 2 days after its arrival at Finschhafen, all personnel of the hospital worked almost continuously to clean out the bamboo and undergrowth with machetes, so that the jungle could be pushed back far enough for tentage to be erected. The undergrowth was luxuriant, and some of the stalks were 3 inches in diameter and extremely difficult to cut down by hand.

In both Milne Bay and Finschhafen, the hospital was under tentage most of the time. A ward tent housed the X-ray equipment, and a darkroom tent was erected behind it. The canvas soon rotted, mildewed, and began to leak. After this happened, native labor was used to build enclosures with thatched roofs but otherwise open to the outside air at all times. Mosquitoes and other insects were numerous, but at least the equipment was kept dry, and personnel were relatively dry. After the hospital had been in Finschhafen for several months, Seabees poured concrete bases for prefabricated, screened huts with corrugated tin roofs.

In September 1944, the 1st Field Hospital, which had previously functioned under USASOS (U.S. Army, Services of Supply) and under the commanders and surgeons of the areas in which it was located, was assigned to the Sixth U.S. Army for the Leyte landing scheduled in October. It staged at Aitape in New Guinea.

The hospital was unable to land on Leyte until D+4, because U.S. fighter cover was insufficient; there were repeated strafing attacks by Japanese light planes and some enemy naval activity. When the hospital finally landed, it was to find that its original assignment had been taken over by an evacuation hospital that had come in earlier, before enemy activity began. This hospital was repeatedly strafed, and several patients were killed.

The 1st Field Hospital first set up near Carigara. Shortly afterward, one platoon was moved to Ormoc, where it operated a 100-bed field hospital on a slightly sloping, hilly area, the appearance of which suggested that drainage would be excellent. It was not. The nature of the soil, plus the incessant rain, kept the area ankle deep, or deeper, in mud. The transportation of patients to and from the X-ray tent was therefore quite a problem. Wheeled litters were out of the question, and hand-carried litters offered the only solution. Patients from all three platoons were evacuated to an evacuation hospital 6 or 7 miles to the rear.

The 1st Field Hospital was scheduled to land with the Sixth U.S. Army on the west coast of Luzon about 1 May 1945. These orders were changed, and it landed instead on the northern coast of Mindanao with combat troops and under small arms fire, which continued after the landing, though tons of U.S. bombs had previously been dropped on the coastal area.

The hospital first set up about a hundred miles from the beach, and, as usual after its move to a new location, it accepted patients within the hour. By this time, the enlisted men in the unit had set up tentage for the receiving office, operating rooms, X-ray department, and one ward. Additional ward tents and the mess tent were then set up.

When topography permitted, the usual plan was to set up a central pyramidal tent, which served as a nursing station, with the operating room, X-ray tent, and ward tents erected off it.

Red Cross and other markings to indicate the character of the installation were never used; the 2d Field Hospital in northern New Guinea, which was so marked, underwent direct bombing.

The first X-ray work on Mindanao was limited to combat casualties. Later, patients with malaria and dengue fever were also examined.

When the hospital moved inland, it was located in a pineapple plantation, on the brow of a small hill, in front of a unit of 75-mm. howitzers, which persistently lobbed shells over the hospital into the Japanese lines. The Japanese apparently had no heavy artillery in the area, for the fire was not returned.

In this location, as elsewhere in the combat zone, the hospital was responsible for its own guard duty, and X-ray technicians took their turns serving on the perimeter. For tactical reasons, the nurses assigned to the hospital were seldom used in such forward areas; when they were, additional guards were necessary for their protection, which meant an increase in overhead personnel.

By the end of June, the situation on Mindanao was more or less stabilized, and the 1st Field Hospital was assigned to the X Corps, with which it served until the end of the war.

When the hospital acted as a station hospital, the X-ray department treated superficial skin conditions, the maximum load being about 40 a month. The diagnostic load during station hospital periods was about 20 a day.

HAROLD A. VINSON, M.D.

EVACUATION HOSPITALS

1st Evacuation Hospital

The 750-bed 1st Evacuation Hospital first operated under canvas near Rockingham, N.C., where it serviced troops on maneuvers in the immediate field area. This experience gave the X-ray department an excellent opportunity to test field equipment, which was found to be exceptionally well adapted for the purpose intended; it was easily set up and extremely durable. The members of the technical staff who came from the Army school for technicians were exceptionally well trained to handle their assignments.

The workload consisted chiefly of training and traffic accidents, with an unusually large proportion of head injuries caused by maneuvers during blackouts.

During these maneuvers—and, in fact, until the hospital operated at its second station in Australia—it operated under a World War I table of organization, under which the radiology and sterilization sections were set up in the same tent, under the supervision of the radiologist. The sterilizing equipment was all in good condition but was of World War I vintage; the newspapers in which it was wrapped bore 1918 dates. The radiologic personnel did their best to supervise its use and operation, but this was an odd and inefficient arrangement. Medically, radiology and sterilization are at the opposite ends of the spectrum.

The 1st Evacuation Hospital arrived in Brisbane early in April 1942 and was sent at once to Gatton, where the 153d Station Hospital was already operating. Here it was divided and distributed around the Brisbane area, to care for small dispensaries handling troops in these various locations. A small base dispensary with a dental unit was set up in the office of the Area Surgeon to handle general medical work. The X-ray work for this dispensary was done at the hospital then being set up at Indoorpilly, in the buildings of the Nudgee Junior College, supplemented by some prefabricated buildings. This hospital, which was a considerable distance from Brisbane, was ready by the time casualties from the Battle of the Coral Sea began to be received, in May 1942.

The radiologist, Capt. (later Col.) Vernon L. Bolton, MC, was sent to the surgeon's office in Brisbane to make some inquiries about pay and was immediately attached to his staff, on which he served until fall. As a radiologist, Captain Bolton was of assistance in receiving and sorting equipment and in the design of some electrical devices, but much of his work was not related to radiology. It included setting up bivouac areas and inspecting kitchens. Fortunately, during this period, the radiologic workload at the 1st Evacuation Hospital was not very heavy. There was no combat, and the examinations were chiefly routine and for civilian-type trauma.

The difficulties of operating U.S. Army equipment with Australian power are described elsewhere (p. 616); all hospitals experienced them.

In September 1942, the 1st Evacuation Hospital moved from the Brisbane area to Rockhampton, where it occupied buildings designed by U.S. Army engineers and built by Australians to house a large evacuation hospital designated to support the 41st Division, which was on maneuvers nearby. The hospital was of the cantonment type and, by this time, as already noted, the radiology department had been able to get rid of its sterilizing duties.

The X-ray work was chiefly of the station hospital type, including routine examinations, injuries during maneuvers, sinus X-rays, and a considerable amount of gastrointestinal work. Fluoroscopy was usually done at night, because of the extreme heat, which also made it difficult to enforce the rules about wearing protective aprons and gloves.

There was no protection around the X-ray equipment, and Captain Bolton expressed the fear that if monitoring devices were used the personnel would be found to be receiving rather large amounts of scattered radiation.

While the hospital was at Rockhampton, the SS *Rufus King*, which was carrying most of the equipment for a number of field and general hospitals, ran aground, broke in two, and finally sank just off the mouth of the Brisbane River. It was possible, by the use of small craft, to salvage most of the X-ray equipment on board, and it is a tribute to its fundamentally sound construction that after it had been dried out, cleaned, and reassembled, much of it was in good working order. The chief difficulty connected with the operation concerned the salvage laws: The boat was in Australian waters, and Australian salvage vessels were available.

When the maneuvers began to be scaled down and troops were moved to New Guinea for the Buna-Gona campaign, the 1st Evacuation Hospital was divided into three units. One continued to operate the hospital at Rockhampton. The others went into tent hospitals to train for the New Guinea operation. The lessons learned on the North Carolina maneuvers now stood the X-ray personnel in good stead; they could set up the X-ray equipment and have it ready for service in a remarkably short time.

In January 1943, one unit of the 1st Evacuation Hospital was set up on the airstrip at Port Moresby, to support both Ground and Air Forces. X-ray service was available, but the load was very light. In this location, the medical problem was the treatment of malaria, not combat trauma.

Portable surgical hospitals were marched over the Owen Stanley Range, with the hope and expectation that they could render medical service in the Buna-Gona area. These hospitals did not have X-ray equipment.

By March 1943, all three sections of the 1st Evacuation Hospital had arrived in Oro Bay, on the north shore of New Guinea. Here one unit was set up on a hillside overlooking the bay, to operate both as an evacuation hospital and as a small station hospital. Hospitals in nearby combat areas evacuated their casualties to it by both air and water.

For purposes of concealment, the tents were laid out along one side of a hill near a ravine, where there was considerable tree cover, with corpsmen in one area and officers in another. Careful protection was necessary, for the

hill served as a turning point for Japanese planes coming in over the base and turning for their bomb runs as they went back out to sea. They came over the hospital area many times, with very clear visibility and often with their bomb bay doors already open, but the hospital was never hit.

At Oro Bay, the 1st Evacuation Hospital handled a general run of patients, including traumatic cases and gastrointestinal examinations. Each flareup of combat activity in the area brought an increased number of gastrointestinal complaints, and many gastrointestinal examinations were necessary to be certain that men who were genuinely ill would not be sent into frontline activity. These examinations were usually made at night, after the evening meal.

While one unit of the hospital was thus engaged at Oro Bay, the other two units were in bivouac nearby. The original plan of building a hospital in the Warisota area proved completely unfeasible; the low-lying coconut plantation in which it was to be erected was constantly flooded by the incessant rains, and fungi and mold, which grew luxuriantly in the wet, moist shade, also made the site untenable. When it was abandoned, the hospital was set up in a more suitable location, in a saddle-shaped area between two mountains, in which drainage was adequate. Here the entire hospital was set up, under canvas, over an area of about 10 acres, with provision for its 750 beds to expand to 1,000 beds.

Mold and rot soon destroyed even the high-grade U.S. Army tentage, and improvised buildings were substituted for the tents. With the help of native labor and with the use of prefabricated material, long wards were constructed of poles and paper roofing. This type of roofing, as was expected, did not last very long, and it was soon replaced with sheet metal covering.

The structures just described were entirely open on the sides except for the operating rooms, surgical wards, kitchen, and X-ray department. The X-ray department was in a separate building in the surgical area, where it could readily serve both the surgical wards and the operating room. Power was secured through two large generators, and an X-ray gasoline generator, with an auxiliary hookup, was also available when it was needed.

The X-ray building was quite well constructed, of poles and sheet metal roofing, with sheet metal used as a base for walls and cloth used as screening from the sheet metal level to the roof. Two radiographic rooms were set up, one on each side of a central darkroom. Fluoroscopy was possible in one of the radiographic rooms by pulling a sliding panel down over the cloth-screened window. The arrangement was practical but not entirely satisfactory because of the extreme heat and, as previously stated, fluoroscopic examinations were made mostly at night.

When the 1st Evacuation Hospital became operational in this location, it was the only hospital operating on the north shore of New Guinea. It therefore received a great many combat casualties; since malaria was under control, the traumatic load was proportionately heavier and the X-ray depart-

ment was kept busy, 50 or more examinations being made daily. The demand for gastrointestinal examinations was still heavy at the announcement of each campaign, and an impossible load was placed upon the field equipment, with which the hospital was still operating. Special regulations therefore had to be made to handle these requests (p. 661).

In New Guinea, usually three to five technicians in the department divided the duties in the radiographic rooms and the darkroom. They also handled the secretarial work and rotated on night calls.

As the war gradually moved away from the northern part of New Guinea, the duties of the 1st Evacuation Hospital became more and more those of a fixed hospital. It was therefore designated the 362d Station Hospital. Later, as the demands for definitive hospital care increased, its designation was again changed, and it became the 248th General Hospital. In the latter capacity, it also operated a convalescent unit on the beach and cared for all cases which regulations permitted. All other patients were evacuated to the Zone of Interior. X-ray service for this new mission continued to be rendered with the Army field unit, which was still entirely satisfactory.

The 1st Evacuation Hospital finally went to the Philippines as the 248th General Hospital, with the X-ray department in charge of Maj. Daniel L. Doherty, Jr., MC, who had succeeded Captain Bolton in this position when the latter became commanding officer of the hospital.

VERNON L. BOLTON, M.D.

168th Evacuation Hospital

The 900-bed 168th Evacuation Hospital was formed in Hollandia in the fall of 1944. The radiologist was Capt. (later Maj.) Walter J. Stork, MC, who had originally been assigned to the 51st General Hospital at Hollandia. He had exactly 5 days to train his X-ray technicians who, in civilian life, were variously a metallurgist, an ex-priest, a sign painter, a bacteriologist, a photographer, a bookkeeper, a laborer, and a student.

Equipment consisted of three machines operated by current from a $1\frac{1}{2}$-hp. gasoline generator. The department could become operational in $2\frac{1}{2}$ hours.

The 168th Evacuation Hospital was first stationed in Biak, in bivouac. Here it performed routine dispensary work. In addition to this type of work, the X-ray department also served the ship and station hospitals in the vicinity. Late in February 1945, the hospital gave direct support to the 41st Division in the Palawan landing in the Philippines, where it operated for $3\frac{1}{2}$ months. It received the few casualties from the invasion; numerous American POW's (prisoners of war); and Air Force casualties, many of whom suffered from fatal internal injuries and burns. The X-ray work was what would be expected in a hospital that really acted as a clearing center for general hospitals, to which the patients were evacuated by air.

In June 1945, after the landing at Zamboanga in Mindanao, the hospital served as a dispensary and operated an X-ray clinic for the local civilian general hospital. Captain Stork organized the X-ray department at this hospital and trained a female technician.

In September 1945, the 168th Evacuation Hospital moved to Davao, in the northern part of Mindanao, where preparations were made for the invasion of Japan in October. On 21 October 1945, the hospital sailed to Matsuyama, Japan, where it operated temporarily in tents in an abandoned Japanese Marine station area. Nearly all the casualties treated had sustained their injuries as the direct result of cleaning out boobytraps and mines previously set by the Japanese.

The hospital served in Japan until February 1946. While it was there, the radiologic personnel participated in many meetings held by field, evacuation, and general hospitals in the area. The meetings were generally well conducted and the discussion of the clinical material was profitable.

WALTER J. STORK, M.D.

STATION HOSPITALS

18th Station Hospital

When the 18th Station Hospital was located at Charters Towers in Australia in July 1942, its principal duty was to provide medical service for the 5th Bombardment Squadron, whose base of operations was nearby. The work was routine, and the load of the X-ray Department was never heavy. The radiologist was Capt. (later Maj.) Frederick W. Van Buskirk, MC.

In October 1942, the hospital was transferred to Iron Range, Australia, at the extreme tip of Cape York. This was totally uninhabited territory. The nearest village, Coen, was 180 miles away and had only 20 inhabitants. The mission of the 18th Station Hospital was to provide medical service for the engineers who were building an airbase at Iron Range. At this period of the war, the Japanese still had the initiative, and they were attempting desperately to cross the Owen Stanley Range, conquer Port Moresby, and use that base as a springboard for an invasion of Australia. Had they succeeded, the planned base on Iron Range would have been extremely important. Since they did not succeed, it was never important.

Within a month after the arrival of the hospital, when the safety of Port Moresby seemed assured, the Air Force moved out, but the hospital was left there for another 4 months, to service the 200 troops still in the area. There were seldom more than 20 patients, and usually there were more medical officers than patients. When the hospital finally received orders to go to Milne Bay, it was one of the few units in the SWPA that was ever enthusiastic about being sent to New Guinea.

When this hospital reached Milne Bay, it again found itself surplus:

An evacuation hospital and a station hospital were already operational there and were providing all the service necessary.

F. W. VAN BUSKIRK, M.D.

125th Station Hospital

After staging in Australia, the 125th Station Hospital arrived in Milne Bay in November 1943 and was immediately put to work constructing its own hospital out of very hard Australian lumber and tin roofing and siding. For some weeks it was the duty of the radiologist, Maj. Donald B. Fletcher, MC, to supervise the laying of the concrete floors. That radiologists should share in the construction work was a perfectly fair arrangement. That the only Board-certified radiologist then in New Guinea should be utilized for this purpose, when there were several functioning hospitals in the area without trained radiologists, seemed a misuse of qualified radiologic personnel, especially as the enlisted men from the engineering corps whom the radiologist was supervising knew much more about the work than he did.

The hospital was located on the side of a hill, with the X-ray building next to the operating room. The first day the operating room was used, while an appendectomy was in progress, the operation was interrupted by a flash flood that followed a sudden heavy rainfall. The X-ray building escaped.

The X-ray department was kept quite busy in this location because of the fighting farther up in New Guinea, particularly at Buna, and the accidents ordinarily encountered on a large base.

Within a few months after the 125th Station Hospital arrived at Milne Bay, the radiologists in this area formed a Milne Bay Roentgen Ray Society, which functioned as any similar society would function in civilian life. Although the organization was entirely unofficial, the discussions at the meetings improved diagnostic ability and provided intellectual stimulation in a situation in which that property was generally lacking.

DONALD B. FLETCHER, M.D.

GENERAL HOSPITALS

35th General Hospital

The 35th General Hospital arrived at Milne Bay, New Guinea, on 25 March 1944. A month later it was transshipped to Lae, where its personnel began to erect quarters for a 1,000-bed hospital in a partly cleared, swampy area of jungle, from which pythons and pigs had to be chased at intervals.

There were two types of buildings, prefabricated buildings set on slabs of hastily poured concrete, and the ward type, constructed with poles, canvas, and wood flooring.

The X-ray department was housed in a prefabricated building near the operating room. The building was large enough for a general radiographic

room; a small fluoroscopic room; a darkroom; and a combination office and viewing room, with space for files.

Since casualties were much lighter than anticipated, the workload was always minimal. Of the 16 X-ray technicians, 12 were soon released for other duties. During the fall of 1944, as the fighting moved northward, the patient load continued to dwindle, and the hospital began to function as a pool of medical officers rather than an active installation. By the first of January 1945, only a skeleton staff remained.

During this period of inactivity, Lt. Col. Horace D. Gray, MC, the radiologist, began a class in X-ray interpretation. Clinical teaching material was limited, for, once malaria was under control, the morbidity at Lae was as low as at any post or camp in the Zone of Interior. Nonetheless, the course, which lasted almost 4 months, was well attended by both U.S. and Australian medical officers.[2]

HORACE D. GRAY, M.D.

42d General Hospital

Within a month after the 42d General Hospital (the University of Maryland affiliated unit) had been activated in the Zone of Interior, it was on the high seas bound for Australia, where it arrived on 19 May 1942. It was first located at the Royal Park Zoo in Melbourne, in tin huts, with no heat. The Army straw mattresses and cots were entirely inadequate for the cold, damp nights.

The hospital then moved to an equally cold and damp staging area near Brisbane. Two weeks later it moved again, into the Stuartholme Convent of the Sacred Heart, which had been converted into a hospital (fig. 197).

Here the X-ray department, which was on the ground floor, consisted of two radiographic rooms, each equipped with field units; another room for cystoscopic work; a darkroom; an office, with secretarial space; and a waiting room area. This area and the space for the secretary had been used as a bomb shelter, and the supporting walls and crisscrossed beams had to be removed. A maze of standard type was constructed for the darkroom.

Since the hospital was small, equipped to handle only 250 patients, the X-ray work was routine, consisting chiefly of accident cases and other civilian-type trauma, as well as the illnesses to be expected among concentrations of troops. The work would have been heavier than it was except that part of the hospital was a convalescent camp and another part, a neuropsychiatric section. At times, almost all of the patients were casualties evacuated from New Guinea, with Daisy Cutter bomb fractures (p. 688). One of the patients in the officers' ward was a cavalry general who had sustained a comminuted fracture of the os calcis while running an obstacle course with his men. Gastrointestinal work was relatively heavy.

[2] Colonel Gray was later assigned to the 49th General Hospital (p. 690).

During the 18 months that the 42d General Hospital occupied the Convent of the Sacred Heart at Stuartholme, a cantonment type of hospital, of 2,000 beds, was being built for it outside of Brisbane, at Highland Park. It was occupied on 15 November 1943.

A number of changes had to be made at once in the X-ray department of the new building. The office space for the radiologist proved insufficient, and it was turned over to the three civilian secretaries. Two portable huts were built onto the X-ray building, one used as a reading room and the other as an office for him.

The darkroom proved entirely inadequate. It was necessary to build larger tanks to take care of the workload, to increase the working space, and to construct a passbox in the wall, through which wet films could be passed out to the medical officers who wanted to examine them immediately. A workbench for loading and unloading films was also built. The waiting room intended for X-ray and other patients was taken over for a viewing and filing room. A large piece of frosted glass was obtained and a 4-panel view box constructed. Underneath it were files of the most recent films, which were most likely to be called for.

The department eventually had a 200-ma. General Electric single tube unit with a 500-ma. generator; a 200-ma. double tube Keleket unit; a 100-ma. tilt table; a cystoscopic unit with Young table; four portable Picker 30-ma. mobile units; a conventional stereoscope and cassette changer; a 200-kv. therapy unit; and all necessary office equipment, including a dictating machine and an intercom set. The dental unit, which had been assigned to the X-ray department, was transferred to the dental department.

On 1 November 1944, Maj. Charles W. Reavis, MC, who had continued as head radiologist while he was Acting Consultant in Radiology, was relieved by Maj. Joseph L. Morton, MC. By this time, Brisbane had become a rear echelon, and the hospital was receiving only garrison troops and patients waiting for transfer to the Zone of Interior.

The hospital was then ordered to Manila, which it reached on 9 June 1945. Its equipment was stored in the Quezon Supply Depot while personnel staged at the Wack Wack Country Club until hospital construction was completed on 14 August 1945, the day of the Japanese surrender. Just as the X-ray equipment was about to be uncrated and the hospital was ready to become operational, orders for Japan were received.

The stay in Manila, although brief, was highly profitable. The Philippine physicians were extremely cordial, and U.S. medical officers visited the leprosarium and had demonstrations of tropical diseases such as yaws, filariasis, and lung fluke. Many medical officers who had belonged to the X-ray society in Milne Bay (p. 695) were in Manila, and the Manila Roentgen Ray Society, composed of both U.S. and Philippine radiologists, was formed. It is still active (1963).

When the hospital was alerted to go to Japan to care for released POW's, X-ray equipment was limited to 4 tons. This was not enough for a full setup,

but the items selected proved to be adequate. They consisted of a field table, a fluoroscope, a gasoline-driven electric generator, a darkroom tent, and enough lead sheeting to make up the remainder of the allotment.

When the hospital arrived in Japan, on 30 August 1945, released POW's were just beginning to arrive, at first singly, then in small groups, and then in groups of 1,000 to 2,000. They were met, bathed, fed, interrogated, and examined medically in that order.

By the end of the third week of operation, the hospital had processed about 40,000 POW's. About 20,000 were examined fluoroscopically for open chest lesions, but the positive yield was so small (less than 0.1 percent) that thereafter only those with signs and symptoms were examined. A very simple technique was used: The darkroom tent was set up inside a warehouse, and the fluoroscope was set up inside the tent. The screen was vertical and fixed from free vertical travel. To screw it up and down would have been too time consuming and too exhausting. The radiologist stood or sat in front of the fluoroscope, and the man to be examined slid between the screen and the rail. Tall men squatted on the rail. Shorter men stood. It required only a glance to determine the presence or absence of gross lesions. Then the next man was fed into the slot.

During this procedure, the radiologists wore lead aprons and also wore dental films for several days at a time. Since there was never any appreciable change in the films, it was concluded that the procedure was safe.

After this mission had been completed, all department heads in the 42d General Hospital were sent to Tokyo to supervise the taking over from the Japanese of St. Luke's Hospital, which became the Tokyo General Hospital. There were only about 40 patients in the hospital at this time, all with typhoid and other infectious diseases. They were soon transferred.

The X-ray department was housed in a wing on the first floor, half of which had previously been occupied by the pediatric department. The department had a General Electric Maximar machine, a deep ray therapy machine, and an old General Electric 200-ma. generator with nonshockproof tube. There had been at least two, and possibly three, rooms of half-wave rectified Japanese equipment with 2-valve tubes, but since all of it was worn out or broken and apparently had not been used for some time, it was discarded. It could not have been repaired since its manufacturers had all been bombed out of existence.

The work in this location was never heavy. On one occasion, 200 Japanese girls to be employed as waitresses and elevator operators in the Daichi Building were X-rayed en masse. The task presented some problems of identification, and further problems arose from the lack of gowns. After Major Morton had been told by a Japanese-American woman that there would be no objection to the procedure, he simply had the girls strip to the waist and line up for the examination, which was accomplished without difficulty.

CHARLES W. REAVIS, M.D.
JOSEPH L. MORTON, M.D.

49th General Hospital

In November 1944, the 49th General Hospital, which had been at Milne Bay, embarked for the Philippines on a Liberty ship. On the first day out, the boat ran on a reef for about 90 feet of its length. The tugs that finally arrived could not pull it off, but on the third day, when the captain said there was no alternative except to throw overboard all the equipment, including the X-ray equipment, the ship suddenly floated free. A 20° list to starboard, however, was maintained during the remainder of the trip to Leyte.

On the first day after the ship arrived on Dulag, kamikaze planes attacked. It suffered no damage, but a ship lying next to it suffered a great deal. The plane plunged into the middle portion, killed a considerable number of persons, and completely destroyed a good deal of equipment, including a new fluoroscope and a developing unit.

The 49th General Hospital at this time was well staffed with competent medical officers, and it treated many personnel from Gen. Douglas MacArthur's staff, members of his family, and a number of important Philippine civilians. The personnel of the X-ray department, which was directed by Major Fletcher, became very friendly with the X-ray personnel at St. Luke's Hospital in Manila, which was then directed by Dr. Paulino J. Garcia, who later became Secretary of Health in the Philippine Government. Conferences were held weekly, and the Manila Roentgen Ray Society (p. 695) was formed and met monthly at St. Luke's to discuss baffling and otherwise interesting cases.

During this period, the activity at the 49th General Hospital resembled that of any large civilian hospital. From the radiologic point of view, it was both productive and satisfactory.

DONALD B. FLETCHER, M.D.

105th General Hospital

The 105th General Hospital, which was formed from the 5th General Hospital (the Harvard Unit), arrived in Gatton, Queensland, Australia, on 11 July 1942 and took over the Gatton College buildings, formerly occupied by the 153d Station Hospital. By late 1942, the hospital was receiving casualties from the New Guinea campaign in increasing numbers, and the flow continued into 1943.

The X-ray department of the 105th General Hospital took over the space formerly occupied by the same department of the 153d Station Hospital and also took over much of its equipment. The first weeks in this location were spent in installing two large 200-ma. X-ray machines and in redesigning the floor space. A partition was erected to create separate radiographic and fluoroscopic rooms. The latter room was made lightproof and it was also, as was painfully discovered in the hot, humid months to follow, made airtight.

The original personnel consisted of two medical officers and three enlisted men. By December 1942, the work had increased sufficiently to require the services of three medical officers and six enlisted men, as well as a civilian

secretary. At this time, the professional staff consisted of Capt. (later Col.) Donald P. Ham, MC; Lt. (later Maj.) John F. Sheehan, MC, and Lt. (later Capt.) Ralph C. Moore, MC.

On 1 December 1943, the X-ray department offices were moved into a new surgery building, which had just been opened, but the equipment was left in its original location. This was not a good arrangement, since the patients were processed in the office before they were examined, after a rather long walk down a boardwalk, in the radiographic and fluoroscopic rooms.

Minor items of supply were always a problem. Typewriters arrived without ribbons. There were no appropriate cassettes for the 14- by 17-inch films. Overall, however, the department and the whole hospital fared very well indeed. Capt. Charles Shelton, MAC, was an extremely competent supply officer. He personally checked every incoming item and seemed to know the exact location of the 176 truckloads of equipment spread over the 10 large ward tents which the hospital occupied. The secret of his operation, he explained, was that, since he did not know what red tape was, he did not try to cut it. He simply instructed his very efficient noncommissioned helpers to bring the requisitioned supplies directly to the hospital from the ship from which they were unloaded, instead of turning them in to the port quartermaster for reissue. The 105th General Hospital was one of the best supplied hospitals in Australia, and when it was required to outfit two portable surgical hospitals, it had no trouble doing so.

The heaviest volume of work was accomplished between April and August 1943. In the fiscal year ending July 1943, the 3,313 examinations made were divided as follows:

Part examined or type of examination	*Number of cases*
Chest	810
Extremity	784
Dental	410
Gastrointestinal series	270
Spine	266
Head	142
Sinus	124
K.U.B.	110
Retrograde pyelogram	103
Barium enema	78
Gallbladder	69
Intravenous pyelogram	49
Jaw	35
Mastoid	30
Encephalogram	20
Bronchogram	4
Urethrogram	4
Myelogram	4
Venogram	1

Up to May 1944, 18,000 patients had been examined. Some medical officers read as many as 70 films a day, in addition to performing other duties. By the end of 1943, however, the patient load had dropped sharply.

In the following year, the hospital was moved first to Hollandia, New Guinea, and then, in October, to Biak, where the work was very heavy; and 50 and more patients were examined daily. The hospital buildings, including the X-ray department, were little more than tin roofs, with just enough lumber to support them and with eaves just wide enough to keep the rain out.

RALPH C. MOORE, M.D.

132d General Hospital

The 2,000-bed 132d General Hospital was set up in tents when it arrived in Biak in the Schouten Island Group except for the administrative department, the operating room, and the X-ray department, which were set up in corrugated iron buildings of the barracks type, with partly opened sides.

The X-ray building was 20 by 72 feet, which provided floor space of 1,440 square feet. At one end were the two radiographic rooms, with provision for fluoroscopy and a cassette changer nearby. The darkroom, viewing office, and department administrative office were at the other end.

The X-ray department began to function 48 hours after the hospital opened, with a single field unit operated by a small mobile gasoline generator. After larger generators had been installed for the whole hospital, as many as eight field units could be used. Like the hospital, the X-ray department was kept busy during the campaigns in the Philippines, from which it received casualties. At one time, the hospital census was 2,400.

Technical personnel were extremely efficient. The chief technician could repair anything in the department, even the highly vulnerable cooling unit. It was later found that his technical achievements did not end there; he was also operating a still in the coral cliffs, though how or with what was never discovered.

Two other large general hospitals, the 9th and the 105th, were near the 132d General Hospital on Biak, within half a mile of each other, and the relations of the radiologic personnel were close and cordial. The Schouten Island Radiologic Society was founded, and meetings were rotated among the three hospitals.

Cordial relations also existed with the Dutch Government Hospital on Biak, which was a part of the Netherlands East Indies.

A small native hospital nearby was staffed by a few Malayan physicians. On several occasions the director, who was a graduate of the Medical School of the University of Soerabaja on Java, brought over native patients to be examined. The request was gladly acceded to, since it gave the radiologists some experience with endemic yaws.

Soon after the Japanese surrender, the 132d General Hospital was closed (later it was sold in entirety to the Dutch East Indies Government), and its personnel were distributed among the hospitals in Manila. Maj. (later Lt. Col.) Egon G. Wissing, MC, the radiologist in charge, was first assigned to the 60th General Hospital, located at San Beda College in Manila. This

hospital, which operated in a well-preserved stone building, was soon closed and Major Wissing was designated to set up the X-ray department of the entirely new 1,000-bed 311th General Hospital, located 8 miles from Manila. As soon as all departments were in good working order, the hospital was turned over to the Philippine Government and became the 1st Philippine Army General Hospital.

Major Wissing was transferred to the 4th General Hospital, which was then located in one of the permanent Army installations at Fort William McKinley, outside Manila. The hospital census was fairly large, and released POW's were still arriving, but the X-ray procedures were chiefly routine, including examination of officers and others ready for departure to the United States.

EGON G. WISSING, M.D.

HOSPITAL SHIPS

To complete the record of X-ray facilities in SWPA, mention might be made of hospital ships.

The *Tasman*, which became operational in August 1943, transported convalescent casualties from Port Moresby and Milne Bay and Oro Bay to Australia. Subsequently, it was assigned to the Philippines.

The ship had on its main deck an operating theater and an adjoining X-ray department and darkroom. The entire area was air conditioned, which made it highly efficient for tropical use. The hospital had a capacity of 276 beds, and during its first year of operation it made 72 trips, traveling a total distance of 138,095 nautical miles. During this period about 300 X-ray examinations were made.

The X-ray room, about 12 by 12 feet, was on the forward starboard side of the main deck and was readily accessible from the nearby elevator and the loading ports. Equipment was the standard Army field unit with removable tabletop. A vertical wall rack was installed for chest films. Current was supplied by a special 100-volt a.c. generator. The tube current was about 15 ma.

A small darkroom, about 4 by 4 feet, was equipped with tanks containing solution at room temperature.

Capt. Frederick A. Rose, MC, an internist who subsequently became a radiologist, handled the X-ray work, assisted by a corporal with some technical training, who also served as a corpsman on the wards. This technician had helped assemble the equipment, and he determined the basic exposures. Although his training was limited, he was the only person aboard who had any technical knowledge at all.

The chief radiologic difficulty encountered was the severe and constant vibration from a loose propeller shaft on the ship. The affected focal spot was probably in the magnitude of a centimeter or more.

CHARLES W. REAVIS, M.D.

CHAPTER XXXIV

Conclusions and Recommendations

Charles W. Reavis, M.D.

CONCLUSIONS

The preparation of a history long after the events that it relates have occurred has obviously undesirable connotations. The passage of time, however, also introduces a number of advantages, one of which is that the conclusions drawn and the recommendations made are decidedly more objective than they would be if they had been formulated immediately after the events had occurred.

In retrospect, perhaps the most outstanding feature of the radiologic service in all Pacific Ocean areas was the ability demonstrated by individual medical officers to cope with almost intolerable general conditions and with difficult special situations. In these respects, the problems of the radiologist closely resembled those of all other medical officers. The radiologist, however, had a problem peculiar to his specialty, that he could not practice it without functioning equipment. This equipment, which is extremely delicate, proved difficult to operate and maintain in the climatic conditions of the Pacific. It also suffered from the frequent movements of hospitals necessary to keep up with advancing armies. In these circumstances, the radiologist was frequently called upon to be many more things than a radiologist.

The medical profession as a whole realized in World War II more than ever before that radiology is of enormous value in all areas of the body. Extremely valuable information could be gained from radiographic studies even in departments operated by poorly trained radiologists or by medical officers with no radiologic training at all. The simplest examination proved useful; indeed, it often provided information essential for the correct treatment of the wounded casualty. It is fair to say that the advances made in radiology since World War II are largely due to its demonstrated usefulness during the war.

Clinically, special advances were made in the Pacific Ocean areas and elsewhere in the study of fractures and foreign bodies; in the elucidation of congenital and other anomalies of the spine; and in the manifestations, particularly the thoracic and gastrointestinal manifestations, of tropical diseases. Technically, radiology also advanced by the development of new methods and by improvisations that, before the war, would not have been considered practical, regardless of the circumstances.

RECOMMENDATIONS

There is no doubt, whatever forms wars of the future may take, that radiology will play an important role in the medical care of the wounded. For that reason, the lessons learned in World War II must not be forgotten. The following recommendations are based upon the radiologic experience in that war in the Pacific:

1. Some overall plan of operation must be developed for the radiologic service. There was no such plan in any of the Pacific Ocean areas in World War II, and, as a result, much time and effort were wasted, and the service as a whole was less efficient than it should have been.

2. The organization necessary could best be based on a system of consultants, with a chief consultant in each theater of operations and regional consultants serving under him. There was no official provision for consultants in radiology in the Pacific Ocean areas in World War II. The South Pacific never had a consultant. The Central Pacific had only part-time consultants. The Southwest Pacific, the most important of all the Pacific Ocean areas, had only an acting consultant, who served for only a little over a year.

3. The proposed consultants, in addition to being highly qualified and Board-certified radiologists, should be appointed on the basis of their organizing ability and their capacity and determination to implement whatever plans are formulated.

4. Specialists in all fields of medicine will always be in short supply. All of them, including radiologists, should therefore be used only for professional functions. In the Pacific Ocean areas in World War II, they were sometimes, usually of necessity, used for other purposes. Some of them performed the duties of supply officers, health officers, and even engineers. Aside from the fact that radiologists have no training at all in such matters, this is a wastage of scarce professional personnel that should not again be permitted.

5. Provision should also be made for the use of specialized personnel, including radiologists, during periods that hospitals are staging or are otherwise inactive. In the Pacific Ocean areas, many hospitals were without qualified radiologic personnel, or any radiologic supervision, while not too far away radiologists waited, without work, for their hospitals to be constructed and their equipment to be set up.

6. Tables of organization should provide that radiology be a separate service in hospitals in all echelons, with the chief of the service responsible directly to the commanding officer. The radiologic service cannot operate with the highest efficiency when it is part of a medical or a surgical service, no matter how understanding the chiefs of those services may be.

7. Training for technicians should be continued and extended. They are an indispensable part of the successful operation of a radiologic service.

8. Provision should be made for the administration of radiation therapy. In optimum circumstances, equipment should be provided and used only for this purpose, under the supervision of consultants. When such equipment is

not available, it is essential that accurate means of calibrating ordinary equipment be provided. There was little advance planning for radiation therapy in the Pacific Ocean areas, and, as a result, there were losses of manpower that need not have occurred while soldiers who needed this kind of treatment were sent to the rear from combat areas.

9. Special attention must be given to the X-ray section in both the planning of hospitals and their location. This section has special requirements, and, since it cannot operate without its equipment, it should have a special priority in the construction of facilities.

10. X-ray equipment must be developed that will stand up better to climatic conditions, especially tropical conditions, than the equipment provided in World War II. In particular, stamped out darkrooms and leadlined radiographic rooms must be developed and prefabricated, so that X-ray sections can be assembled and set up without delay and operated without risk to personnel.

11. There should be a wiser selection of equipment and accessories for any future emergency. Overall, there was no real lack of radiographic equipment and supplies in the Pacific. On the other hand, both financial expenditures could have been reduced and transportation difficulties could have been decreased if more practical considerations had been taken into account when tables of equipment were devised. The foreign body localizer, for instance, could profitably have been omitted entirely. On the other hand, spot-filming equipment should have been provided with all fluoroscopes.

12. All equipment should be standardized. The varieties used in the Pacific Ocean areas made replacement of parts a continuing problem and interchange of parts practically impossible.

13. A maintenance and repair service should be set up in advance of hostilities. There were no such arrangements in the Pacific Ocean areas. The service finally established proved highly efficient, but it was always a makeshift operation, and much time was lost in the use of equipment before it was set up.

14. A better system of ventilation should be planned for darkrooms. Conditions in them in the Pacific Ocean areas did not make for efficiency.

15. Provision should be made for fresh water for processing films and for keeping the water cool. Developing radiographs was difficult in all the Pacific Ocean areas because of lack of these essential requirements.

16. A better system of handling films in tropical climates should be devised. There was serious wastage of films in the Pacific Ocean areas, as well as transient shortages, because of film fog.

17. Planning for a radiologic service should include refresher courses for staff and technical personnel; for staff conferences; and for contacts between radiologists in adjacent hospitals, whether by formal organization or otherwise.

18. Standard textbooks should be provided for all X-ray departments, and current journals should also be provided. This recommendation is of particular importance when the radiologist serves in an isolated hospital or when the officer in charge of a department has had little or no radiologic training.

China-Burma-India Theater

CHAPTER XXXV

China-Burma-India Theater

Philip J. Hodes, M.D.

Section I. Military and Medicomilitary Considerations

BACKGROUND OF THEATER

The military area which came to be known as the China-Burma-India theater was unique in a number of respects, including its mission, the means by which its mission was accomplished, and the environment in which its operations were conducted.

The environment, as described in more detail later in this section (p. 727), added immeasurably to the difficulties of combat and of medical care, particularly in the India-Burma theater, in which many U.S. troops operated. Temperatures up to 106° F. and over were not unusual. Humidity of 90 to 95 percent was almost routine. The monsoon, a wind of cyclonic character, which blows for 5 months in the year, created havoc in the air and on the ground and also brought phenomenal amounts of rain. In the Assam-Burma mountains, the annual rainfall ranged between 300 and 350 inches and troops were sometimes not dry for months on end. Roads which one day carried medical and other supplies on the next day might be 30 feet under water or no longer there because they had been washed off the side of the mountain. If a road or clearing were not constantly maintained, the jungle would reclaim it within a few weeks. Equipment mildewed, rotted, or rusted, and men were worn out before their time from their battles with the environment.

In this region, traditional medical doctrines were pushed aside by actual situations. The lines of medical evacuation were turned topsy-turvy. Normally, casualties are evacuated from a combat zone with the utmost dispatch. Here, general hospitals frequently received casualties from battalion aid stations and sometimes evacuated their patients to evacuation or station hospitals. Field hospitals sometimes functioned as evacuation hospitals. Collecting and clearing stations sometimes set up facilities which functioned as station hospitals or sent out mobile surgical detachments. Hospitals were sometimes split in two, one side caring for Chinese, and the other for United States casualties. In addition, for long periods of time, each side of such a hospital might operate at the normal capacity of the whole hospital (*1*).

In view of these and other facts, it is necessary, in order to understand the medicomilitary activities of the China-Burma-India theater, to review briefly certain aspects of its development.

ORIGIN OF THEATER

Direct U.S. military involvement in the vast area in the Far East that eventually became the China-Burma-India theater [1] stemmed from the passage of the Lend-Lease Act by the U.S. Congress in March 1941. While the primary objective of this act was to strengthen the British in their desperate defense against overwhelming German forces in Europe, a second, highly important objective was to strengthen the Chinese Nationalist Army in its struggle to defend China against further incursions by the Japanese.

The Chinese Republic was faced with enormous problems: An aggressive enemy without, with designs on vast areas of Chinese territory; a Communist enemy within, bent on seizing power; a society that was still medieval in many respects; an economy in strained condition, ill-adapted to the requirements of modern warfare; a transportation system that was hopelessly inadequate; and, finally, an army that, although large, was of doubtful effectiveness.

Lend-Lease sought to solve some of these problems by supplying the Chinese Army with modern implements of war on a large scale. The solution, however, was attended with major difficulties, including the reduction of Chinese requests for arms to realistic amounts, delivery of the arms, and assurance of their effective use once they had been received.

U.S. Military Mission to China

It was to achieve the objectives just stated that the United States, in the fall of 1941, sent a military mission to China. This mission was first under the direction of Brig. Gen. John Magruder, USA, who had been ordered to the Middle East (Iran) but who was diverted to China while he was en route. He was succeeded by Maj. Gen. (later Gen.) Joseph W. Stilwell, USA. General Magruder's instructions from the War Department were to assist the Chinese Government in the procurement of military materiel; to train Chinese personnel in its use and maintenance; and to study transportation facilities, with the idea of eventually establishing an adequate line of communications.

Creation of China Theater

When the Combined Anglo-American Chiefs of Staff, shortly after Pearl Harbor, began to allocate combined theaters, they did not include China, in the belief that the Chinese would never consent to their country's coming

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[1] Unless otherwise indicated, the political and military data in this chapter are derived from the publication by the Office of the Chief of Military History entitled "Stilwell's Mission to China (2)."

under a foreign command. A separate China theater was therefore designated in December 1941, with President (Generalissimo) Chiang Kai-shek as Supreme Commander. On 5 January 1942, President Chiang agreed to this arrangement and asked for the assignment of an American officer as his Chief of Staff. The War Department selected General Stilwell for this position because he had previously served in China. On 21 January 1942, the Chinese Government agreed to General Stilwell's assignment as Generalissimo Chiang's Chief of Staff and also agreed to his having command over Chinese units, especially those operating in Burma.

Arrival of General Stilwell.—Shortly after his arrival in Karāchi, India, on 24 February 1942, General Stilwell flew to Chungking, China, where he took up his fourfold duties:

1. As Commanding General, U.S. Army Forces in China, Burma, and India.
2. As the military representative of the President of the United States in Chungking.
3. As the dispenser of lend-lease materiel from the United States to China.
4. As Chief of Staff of the Generalissimo's Joint Staff. In this role, he was assistant to a commander who was responsible to no one but himself and whose concepts of China's best interests did not always agree with the concepts of the Combined Chiefs of Staff in Washington.

The original plan was that General Stilwell would go from Chungking to Burma, where he would take command of the Allied Forces there; put an end to existing bickering and rivalries; and create an effective airlift over the Hump to China, to replace the lost Burma Road. His expectation of a command in Burma began to fade almost as soon as he had assumed his new post, for he learned that the British, for a variety of reasons which need not be discussed here, viewed the prospect of his command with only limited enthusiasm.

Creation of China-Burma-India Theater

On 22 June 1942, the War Department instructed General Stilwell, by radio, to issue orders relieving all units and personnel under his command from assignment to Army Group, Washington, D.C., assigning them instead to "American Army Forces in India, China, and Burma." Apparently, both the War Department and General Stilwell regarded this message as sufficient authorization for the establishment of a U.S. theater of operations in China, Burma, and India, and the theater is generally assumed to have been established on this date, even though the authorization was never made more explicit. As a matter of fact, as the number of U.S. personnel in these countries increased and the extent of their responsibilities grew, General Stilwell's staff had already come to conceive of itself as a theater headquarters.

DEVELOPMENT OF HOSPITAL SYSTEM

Initial Arrangements for Medical Care

The first U.S. personnel to arrive in what was later the China-Burma-India theater were provided with the usual organic medical support, but hospitalization, when it was required, was to be furnished locally. This arrangement was another of the respects in which this theater was unique.

The British did their best to provide adequate hospital support for U.S. troops, but in the early hectic days of warfare in the Far East, they were hard pressed to meet their own needs and were poorly equipped to meet those of another nation. Supplies were scarce and hard to come by because of the long and hazardous supply routes and the increased demands being placed on Allied medical facilities. Differences in national and professional standards also affected the quality of hospital care provided U.S. troops.

Arrival of Station Hospitals

The strength of the U.S. Mission to China was originally small, but by the spring of 1942, personnel had increased enough to require the development of U.S. hospital facilities to serve the troops already there and those beginning to arrive in the area in considerable numbers.

In March 1942, the Surgeon, SOS (Services of Supply), Col. John M. Tamraz, MC, was informed by the War Department that the 750-bed 159th Station Hospital would shortly arrive in Karāchi. Soon afterward, he was informed that six additional 50-bed station hospitals (the 95th, 96th, 97th, 98th, 99th, and 100th Station Hospitals) would also arrive in the area. Ostensibly, these hospitals were to be part of the medical structure of the theater, but General Stilwell was informed that he might use them in any way he saw fit. At the same time, he was told that these seven fixed hospitals, plus a small casual organization, were all the medical support the War Department planned for the theater, since it was desired "to limit the number of troops in Burma and China to the number as [sic] can be supported from the areas" (*3*).

Before any U.S. Army hospitals had arrived in the theater, Colonel Tamraz took a lively interest, and played an active part, in the development of suitable hospital facilities for troops in the Karāchi area at North Malir (map 8). This British installation was being made available for U.S. use, presumably through the process of reverse lend-lease, but before it was pronounced suitable for hospital purposes, it required considerable renovation and some new construction.

The 159th Station Hospital disembarked from the S.S. *Brazil*, on 16 May 1942, and within a week, it was in operation in the hospital area in Karāchi, where the bulk of U.S. AAF (Army Air Forces) and SOS troops were then

concentrated. With its arrival, the era of complete U.S. dependence on Allied facilities was ended, and U.S. patients were quickly moved to this hospital from the British military hospital in Karāchi, in which they had previously been cared for.

Defeat in Burma

With the establishment of the 159th Station Hospital at Karāchi, in the far west portion of India, bed capacity, for the time being, at least, seemed adequate for the fledgling theater. Almost immediately, however, the need arose for a second fixed hospital in the far northeast portion of the country. During March and April 1942, General Stilwell and his small staff had vainly endeavored to rally the Fifth and Sixth Chinese Armies, which were fighting in Burma alongside the British, against the invading Japanese. By the end of April, the defense of Burma collapsed, and Allied troops, in General Stilwell's blunt language, took "a hell of a beating."

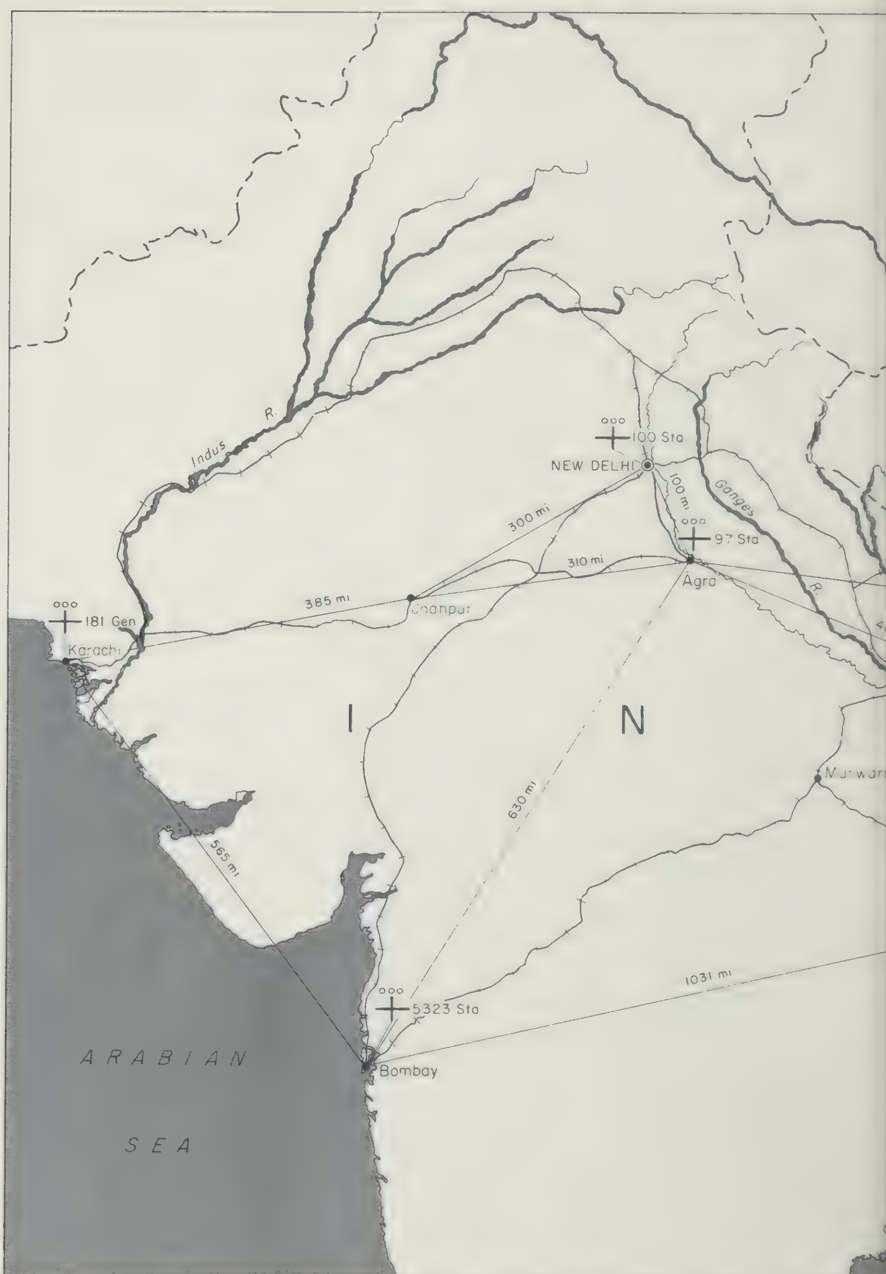
The defeated Chinese troops retreated to north Burma and to China. Elements of the Fifth and Sixth, and most of the Sixty-Sixth, Chinese Armies escaped into China. The bulk of the Fifth Chinese Army, including remnants of the 22d Division, as well as the 38th Division of the Sixty-Sixth Army, retreated into north Burma.

During the first weeks of June 1942, these troops began to straggle into Assam Province, India, where they were met by U.S. staff officers and collected, pending a decision on their status and future utilization. It was finally decided to retain these two Chinese divisions in India; train, reorganize, and reequip them there; and use them for a later counteroffensive in Burma. Negotiations for a training camp were conducted with the British, and in July, arrangements were made for the acquisition of a camp at Rāmgarh, Behai Province, India (map 8). The camp had served as a prisoner-of-war camp, chiefly for Italians, and was in reasonably good condition.

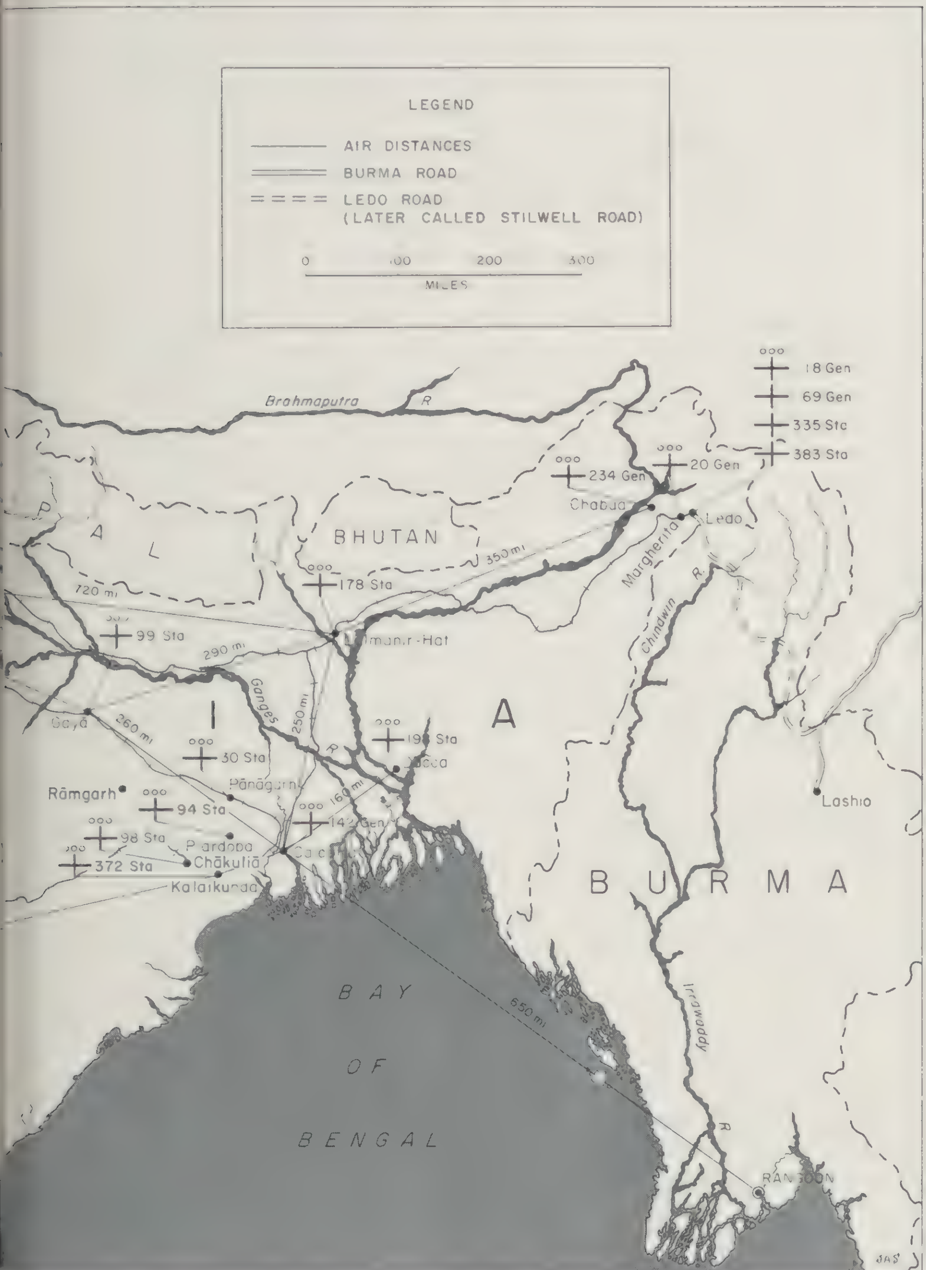
Hospital facilities at the Rāmgarh Training Center.—Accompanying the Chinese in their retreat from Burma was the Seagrave Hospital Unit, a predominantly civilian mobile surgical unit led by Maj. (later Lt. Col.) Gordon S. Seagrave, MC. He had operated a mission hospital in northwest Burma for the preceding 20 years, and his organization later served with the Fifth and Sixth Chinese Armies in the Burma Campaign.

When the camp hospital at Rāmgarh, with other fixed facilities, was turned over to U.S. control, the Seagrave Unit, supplemented by additional U.S. medical personnel, began the medical rehabilitation of the Chinese troops. Most of them needed care badly. They were obviously malnourished and debilitated, and nearly all were suffering, in varying degrees, from tropical ulcers, venereal diseases, amebiasis, malaria, and other tropical diseases.

The census of the hospital at Rāmgarh soon exceeded the 1,000 mark, and the need for additional facilities became pressing. The 98th Station Hospital, which had arrived in the theater in July 1942, was dispatched to Rāmgarh,



MAP 8.—China-Burma-India theater, showing locat



of station and general hospitals as of 31 December 1944.

which it reached on 20 August 1942. At that time, the approximately 1,000 patients in the camp hospital were being cared for by 5 medical officers of the Seagrave Unit, 33 Burmese nurses, and 35 enlisted men. The commander of the 98th Station Hospital, by virtue of seniority, took command of all hospital facilities. The census rose to a peak of 1,326 in September and, then, gradually declined as the Chinese troops were restored to health.

Impact of Ledo Road on Medical Planning

Meantime, another logistic development was underway in the theater, the planned construction of an all-weather road from Ledo, Assam Province, India, through Burma, to the Chinese terminus of the old Burma Road. The new road would permit overland movements of supplies into beleaguered China, which at this time could be supplied only by air over the perilous Hump in the Himalayas. A continuing supply of materiel of war was essential to China's continued effective participation in the war and was also the keystone of U.S. efforts to aid this country.

The building of the Ledo Road portended a greatly increased medical load in the theater. Late in October 1942, to meet the new requirements, Colonel Tamraz requested a 1,000-bed general hospital, three 750-bed evacuation hospitals, and other supporting medical units to provide hospitalization for the estimated 30,000 troops who would be involved in the construction of what was first known as the Ledo Road and was later renamed the Stilwell Road by Generalissimo Chiang Kai-shek.

In November 1942, when Colonel Tamraz went to Assam to select sites for the new hospitals he had requested, he found General Stilwell's headquarters and other military installations already located on some of the tea plantations in the area. The buildings used in processing the tea plants were electrified and were otherwise well adapted to hospital use. The polo field of a group of British tea planters was later used for this purpose.

Further Hospital Developments

The census at the 98th Station Hospital at Rāmgarh continued to fall as greater need arose for it elsewhere. On 1 January 1943, it was moved to Ledo, where it occupied a hastily constructed group of basha-type huts (p. 728) and a few other buildings of more permanent construction. It remained here until April 1943, when it was dispatched to Chākuliā, India.

The replacement for the 98th Station Hospital was the 1,000-bed 20th General Hospital, which arrived at Margherita, Assam, India (map 8), on 22 March 1943, under the command of Col. Elias E. Cooley, MC (*4*). The "dismal and discouraging beginning" of their work is described in detail elsewhere in this section (p. 727). Presented with a great challenge, the hospital personnel lost no time in draining the area, repairing buildings, clearing

away jungles, and cleaning up the surroundings. The work was accomplished with such speed that patients could be received on 2 April 1943. During its period of service in Margherita, from this date until it was deactivated in November 1945, this general hospital sometimes functioned as such, but at various times, it also functioned as a station hospital, an evacuation hospital, and even as a field hospital, depending upon the tactical situation. It provided all types of medical and surgical care, for patients coming not only from Burma but also from China and nearly all parts of India.

Shortly after the 20th General Hospital arrived, the 48th and 73d Evacuation Hospitals arrived and were assigned to Ledo. They were later joined in this location by the 14th Evacuation Hospital. When the 151st Medical Battalion (Motorized) arrived, it was distributed along the trace of the new Ledo Road and along the trails into Burma, to provide evacuation facilities and trail hospitals for isolated working parties.

Located at AAF and ATC (Army Transport Command) bases in central India were the 100th Station Hospital, assigned to New Delhi; the 97th Station Hospital, assigned to Agrā; and the 99th Station Hospital, assigned to Gayā. The 112th Station Hospital, which arrived in Karāchi late in March 1943, was dispatched to Calcutta, where, on 12 August 1944, it became the 263d General Hospital.

Section II. Administrative Considerations[2]

RADIOLOGIC WORKLOAD

Radiologists came into the China-Burma-India theater, with all of the hospitals listed and provided, often under great difficulties, the services expected of a department of radiology in a civilian hospital. Complete figures for the radiologic workload in this theater are not available, but some idea of its size and importance can be gained from the following statistics from an evacuation and three general hospitals:

During 1944, while the 73d Evacuation Hospital was functioning as a semipermanent installation at Ledo, India (map 8), and then at Shingbwiyang, Burma, its Radiology Department examined 6,260 patients, of whom 6,191 were military; of this number, 3,267 were Chinese (*5*).

Between 2 April 1943, when it became operational, and the end of that year, the Radiology Department of the 20th General Hospital made 16,535 examinations on 7,516 patients (*4*). The examinations included 640 studies of the gastrointestinal tract, 215 urographic studies, 4,070 chest examinations, and 714 examinations of the head. In 1944, the department made about 35,000 examinations on about 17,000 patients. In his annual report for 1944, Col. (later Brig. Gen.) I. S. Ravdin, MC, the commanding officer, remarked that,

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[2] Appreciation is expressed to Dr. (formerly Major, MC) George P. Keefer for his assistance to Dr. Hodes in the preparation of the remainder of this chapter.

in spite of the handicaps under which it operated, the Department of Radiology had done as much work during the year as was done annually at the University of Pennsylvania Hospital, and had done it with about a quarter of the personnel.

During 1945, the 142d General Hospital made 20,438 radiologic examinations on 18,861 patients, of whom 90.4 percent were U.S. Army personnel (*6*). Of the remainder, 3.3 percent were U.S. Navy personnel and 6.3 percent, civilians. The total figures included 7,775 chest examinations, 4,567 examinations of the extremities, and 1,515 examinations of the entire spine.

Between 1 January and 15 June 1945, about 80 percent of the daily caseload of the 69th General Hospital passed through the Department of Radiology, probably because, as the bed census fell, increasing numbers of outpatients were seen (*7*).

LIAISON WITH ALLIES

Professional relations with the British, which were always cordial and of the highest order, were established early, when U.S. Army medical personnel operated a small station hospital in Bombay, which served more as a convalescent hospital than as a station hospital. For this reason, all diagnosis and therapy needed by U.S. troops were conducted at the British Army hospital in this city. The arrangement was a harbinger of the professional relations that existed throughout the war. No matter where United States and British installations were located, patients who needed care, particularly those too ill to be moved at once, were cared for at the nearest hospital unit, regardless of whether they were United States or British personnel and regardless of whether the hospital was a U.S. Army or a British Army installation. The medical care of casualties was always the first consideration. Formalities of transfer were cared for later.

Their relations with local British and Indian civilians were, of course, of great importance to all U.S. military personnel in the theater, including radiologists. The British had their own hospitals, but their medical support was sometimes limited, and they did not have the specialized personnel attached to U.S. Army hospitals. For reasons that were never clear to them, U.S. medical officers were discouraged from rendering medical help to civilians, if not actually forbidden to do so. Some fundamental military reason for the restriction probably existed, and it is unfortunate that it was not explained. For many medical officers, the transition from civilian to military practice had been too recent for them to accept without question a regulation in such conflict with the humanitarian principles under which they had previously conducted themselves professionally.

Another reason medical officers objected to this restriction was that, in their eyes, local citizens were supplying U.S. medical personnel not only with items that they needed medically but also with many of the graces and

amenities of life that were entirely lacking in their military environment. For this reason, and in line with the principles of civilian medical practice, the rule that medical care should not be furnished to local civilians was sometimes violated. The staff of the 20th General Hospital—and no doubt the staffs of other hospitals in other ways—was once dramatically repaid for its lapses from military regulations. A U.S. officer developed a rapidly growing testicular tumor which could not be treated at this hospital but for which the necessary treatment could be secured at the Tata Memorial Hospital in Bombay. Except for the rapport existing between the professional staff of the 20th General Hospital and their local British friends, who effected his transfer, this officer might well have lost his life.

TRAINING OF CHINESE PERSONNEL

Once Gen. Sun Li-Jen, Commanding General, First Chinese Army, who was a graduate of the Virginia Military Institute, came to realize that it was decidedly to his advantage to utilize U.S. radiologic and other personnel in the theater for training purposes, he proved most cooperative in this regard. Eighteen Chinese soldiers were assigned to the 20th General Hospital, nine to be trained as laboratory technicians and nine as X-ray technicians. Their commanding officer, whose rank was equivalent to that of major in the U.S. Army, had majored in physics and was able to take over part of the actual training, which was conducted under the direction and supervision of the hospital technical and professional staffs.

General Sun's wise selection of these particular soldiers (fig. 236) made their training a simple matter. Since all of them spoke and understood English well, there were no language difficulties. Within 2 months, they were able to do almost anything required of them in the various capacities in which they served—as X-ray technicians, interpreters, messengers, and litter bearers, among other assignments. The men were an integral part of the hospital, and their skill and diligence came to be accepted as a matter of course. The training they received undoubtedly was of great benefit to them when they returned to their homes after the war.

Their training also proved valuable to the 20th General Hospital: As the Japanese were driven back from Assam and Burma, the hospital was expanded to approximately 3,500 beds, to accommodate Chinese, as well as United States, casualties and a few British casualties. In the ensuing, greatly increased activities, the Chinese X-ray technicians handled all Chinese patients, expedited their care, and eliminated most of the time that would have been spent and the difficulties that would have occurred otherwise in communication between patients and technicians and officers who spoke different languages.

FIGURE 236.—Chinese X-ray technicians, trained at 20th General Hospital, with Lt. Col. P. J. Hodes, MC, Chief of the Radiology Department. From left to right, Sergeant Lee, Major Chiang, Lieutenant Colonel Hodes, Sergeant Chu, Major Chien, and Sergeant Feng.

PROFESSIONAL RELATIONS

Whenever U.S. medical officers were in Bombay, they were invited to lecture and hold conferences at British hospitals. They were sometimes asked to examine British patients. Lt. Col. Philip J. Hodes, MC, while acting as consultant in radiology for the China-Burma-India theater, was several times asked to examine high-ranking Chinese and Indian officers and, on two occasions, high-ranking British officers.

On one of his trips to Bombay, Colonel Hodes met Capt. (later Lt. Col.) David I. Malen, RCAMC, who was acting as radiologist in a large British Army hospital and was rendering dedicated service. As a result of the friendship that sprang up, Captain Malen moved to the United States after the war; became a U.S. citizen; specialized in radiology; was eventually certified by the American Board of Radiology; and is now practicing in Louisiana.

British, Indian, and visiting United States medical officers regularly attended the meetings of the Assam Radiological Society, which was founded at the 20th General Hospital by Colonel Hodes and whose meetings were participated in by radiologists from all the surrounding hospitals (fig. 237). The meetings were held weekly, and the programs included information on new developments in the specialty as soon as word of them reached the theater.

British and Indian medical officers were also warmly welcomed to the medical, surgical, and radiologic staff conferences at the 20th General Hos-

FIGURE 237.—Members of Assam Radiological Society, January 1945. From left to right, standing, Maj. George P. Keefer, MC, 20th General Hospital; Maj. David A. Burlingame, MC, 172d General Hospital; Maj. Edwin L. Rypins, MC, 69th General Hospital; Col. Furman H. Tyner, MC, and Lt. Col. Philip J. Hodes, MC, 20th General Hospital; seated, Capt. Lambert F. Mammoser, MC, 14th Evacuation Hospital; Lt. Col. Webster H. Brown, MC, 18th General Hospital; and Col. Edward M. DeYoung, MC, Commanding Officer, 69th General Hospital.

pital. They frequently expressed their appreciation of the instruction afforded by attendance at them. The Department of Radiology, because of its intimate involvement with all medical practice, had an important role in the medical and surgical conferences as well as in its own specialized conferences.

Section III. Personnel

CONSULTANT IN RADIOLOGY

Although the need for medical consultants in the China-Burma-India theater had become apparent long before, none were appointed until early in 1945, and no full-time consultant in radiology was ever appointed.

The need for radiologic consultant service in the theater was met by the expedient of appointing Colonel Hodes, as Acting Consultant in Radiology, soon after the 20th General Hospital, in which he headed the Radiology Department, began to function in the theater in April 1943. He performed these dual functions from this time until the war ended.

An immediate tour of all fixed hospitals in the theater, supplemented by later tours for special purposes, revealed that, in general, all radiologic departments were performing efficiently, were meeting the demands made upon the specialty, and were improvising equipment and techniques as the need developed. During the course of the war, however, a number of difficulties arose that might have been avoided if a full-time consultant in radiology had been able to anticipate them or to correct them immediately.

One problem was the transfer of trained men from one installation to another by personnel officers who, many times, simply did not understand radiologic requirements and who were not able to evaluate radiologic qualifications. In the European theater, where a radiologic consultant served during the planning for the invasion of the Continent as well as during the active fighting (p. 325), these difficulties were reduced to a minimum.

The appointment of a full-time consultant in radiology would also have gone far to overcome the difficulties and misunderstandings that arose out of lack of communication between radiologists in the theater and the Consultant in Radiology, Office of The Surgeon General, whose advice and assistance would frequently have been useful. It was not until the war was over that Colonel Hodes learned that Col. Byrl R. Kirklin, MC, had served in this capacity in this Office. Colonel Hodes corresponded at intervals with Col. Alfred A. de Lorimier, MC, but the correspondence was not entirely satisfactory, partly because of the long delays in replies to his letters and partly because Colonel de Lorimier was fully occupied with the training courses he was directing in the Zone of Interior.

Communication was also difficult between radiologists in the theater because of the disposition of troops and supporting hospitals. They were scattered over enormous areas, and in a few instances, there were a thousand miles and more between small groups. Ground lines of communication were extremely primitive, if they existed at all, and the ready exchange of information on technical and other points, possible in other theaters by virtue of a functioning consultant system, was never developed in the China-Burma-India theater.

Replacements for specialized personnel, when they became ill or otherwise incapable of duty, were a problem in any theater, where all specialists were in short supply. Nonetheless, had there been a full-time consultant in radiology for the China-Burma-India theater, with knowledge of the qualifications of radiologic personnel and the workload each was carrying, he could have made proper recommendations to personnel officers and accomplished more intelligent replacements.

One final illustration might be mentioned of difficulties that arose from poor intratheater communications. Gastrointestinal disease was relatively frequent in this theater, and peptic ulcer, confirmed by radiologic evidence, was often a reason for evacuating soldiers to fixed hospitals in the rear with the recommendation that they be returned to the Zone of Interior. In a number of instances, patients with active duodenal ulcers were sent from the

forward area to a station hospital in Karāchi with this recommendation. As might have been expected, when they were removed from the forward zone with its pressure and tension, the ulcers became quiescent and healing began. Thereupon, the men were returned to the forward area as fit for duty, apparently without any evaluation of the circumstances under which the ulcers had developed and the original diagnoses and recommendations had been made. Once the men were returned to the atmosphere of tension in the forward zone, again as might have been expected, the cycle recurred and the ulcers again became active and also became increasingly resistant to curative measures.

Better communication between forward and rear installations in the theater might have avoided such a situation. The difficulty was not straightened out until Colonel Hodes had made a special trip to Karāchi and had discussed the matter with the medical officer (a pediatrician) and persuaded him that the interests of the patients in question would be best served by placing more confidence in diagnoses made in forward hospitals. In defense of the pediatrician, who lacked experience in the natural history of duodenal ulcers, two points might be made: He was undoubtedly pressed hard by the scarcity of replacements for soldiers evacuated to the Zone of Interior and, at this time, the policy had not yet been developed of sending their radiographs along with patients who were evacuated.

OFFICER PERSONNEL

The original tables of organization for general hospitals called for three radiologists. By the time most of these hospitals assigned to the China-Burma-India theater had arrived there, the allowances had been adjusted downward and only two radiologists were provided for. As a matter of fact, the chief radiologist often found himself with no assistants at all. Moreover, many hospitals came into the theater with radiologic personnel who were radiologists in name only; they had had no prewar radiologic experience and had been trained for their duties in the short courses given in the Zone of Interior (p. 30).

When only a single radiologist was assigned to a 1,000- or 1,500-bed hospital which was receiving combat casualties, or even when two were assigned, working days of 12 and 14 hours were commonplace.

Early in the war, when there were not enough qualified radiologists in the theater to staff all medical installations adequately or even at all, a system was developed whereby films were sent for interpretation from installations without radiologists, such as aid stations on the Ledo Road, to installations with competent radiologic personnel. Before the war ended, in August 1945, there were a large number of excellently staffed general hospitals in the theater and this expedient became less necessary.

The inflexibility of tables of organization often worked a hardship on competent officer personnel in the China-Burma-India theater as in other

theaters: The tables did not make sufficient allowances for advancement in rank commensurate with individual ability and achievement.

X-RAY TECHNICIANS

Training

The experience of the 20th General Hospital in respect to its complement of X-ray technicians was, unfortunately, not unique: When the hospital was activated in the Zone of Interior, only two trained technicians were attached to it. During the 6-month period it was in training at Camp Claiborne, La., repeated requests for additional technicians went unfulfilled, partly because of Army redtape and partly because of the not unnatural reluctance of other hospitals to release any of their trained technicians to the 20th General Hospital.

Shortly before the hospital went overseas—and, unfortunately, after most of the opportunities for basic training had been lost—three more trained technicians were assigned; one of them had had civilian training in X-ray, and the other two had had the Army short course. Two more technicians designated for the Department of Radiology were assigned to the hospital enlisted men's detachment, in which the emphasis was on general military training rather than on the development of technical skills. Colonel Hodes fully appreciated the need for training in military discipline and for military orientation, but it would have been highly desirable if all seven of his technicians could have had some training and some radiologic orientation before the hospital was sent overseas. It would have made a great difference if, during their training, he could have worked closely with them, followed their progress, evaluated the quality of their work, and built up team spirit.

During the voyage to the Far East, Colonel Hodes conducted classroom instruction and dry-run training sessions for the hospital X-ray technicians. Since there was no X-ray equipment available on board, even in the sickbay, he taught them their duties by rote or by numbers. He also instructed them in the liaison that should exist between technicians and patients and in the relation of technicians to the medical officers who would be dependent upon them for service to their patients.

Obviously, what could be taught on shipboard, with no equipment and with the Army manual the only textbook, was extremely limited. It was, of course, almost unintelligible to men who had never seen an X-ray tube. Much of the professional training necessary had to wait until the hospital was set up in India, and training there could not begin until hospital personnel had cleaned out an area in the jungle in which to set up their facilities and equipment. Once this task was accomplished, the chief technician, who had had some experience with the Picker field unit, began to teach the other technicians how to handle it and how to operate the Army electric generator. During this period, it was found good practice to create problems and then

have the technicians describe how they would handle them. The exercise was ended with a general discussion of all the solutions possible.

Perhaps the most important task of the chief of the Radiology Department on shipboard was his endeavor to impress upon these embryo technicians, inexperienced in their radiologic duties and also new to the Army, the importance of their working as a team. Special emphasis was placed upon the interdependence of the various departments of the hospital upon each other. Emphasis was also placed upon the reliance of radiologists upon films, and upon the responsibility of the technicians for producing them. They were told very plainly that the life of some unfortunate casualty might depend upon the quality of the radiograph which the technician produced, a concept which should furnish a yardstick for all technical work.

Evaluation of Technical Work

Radiologists in the theater were not in agreement as to whether civilian- or Army-trained technicians furnished the more valuable assistance in their departments. The radiologists of both the 18th and the 20th General Hospitals were inclined to believe that civilian-trained technicians did better work. The 18th General Hospital was fortunate in obtaining two experienced civilian technicians when it was completing its complement of enlisted personnel after Pearl Harbor. The 20th General Hospital considered much of the efficiency of its Department of Radiology to be due to its two civilian-trained technicians. One had been a darkroom technician for many years. The other, who served as chief technician, had served in that capacity in a New York City hospital for more than 10 years.

In contrast, the radiologist of one of the general hospitals in the theater commented in his 1944 report that the technical quality of his films was only average because they were made by Army-trained technicians of limited experience. In the 1945 report for this hospital, however, the same radiologist stated that the 11 enlisted men in the department at the end of the year were all well trained, since most of them, before this assignment, had taken the Army course in X-ray technique and had served at various installations in the Zone of Interior.

Whatever the degree of training of their X-ray technicians, all departments found the most practical plan was to put the man with the most experience in charge of the further training of the men of lesser experience. With proper supervision and direction by the chief of radiology, this plan usually worked very well.

MORALE

Morale was an extremely important consideration in the China-Burma-India theater, more so than in either the European or the Mediterranean theater because of the unfavorable environment and climate.

On his first tour of fixed hospitals in the theater, as in all later tours, Colonel Hodes found that the major radiologic problem was not one of supplies or of technique but one of morale. The work was performed under difficult environmental circumstances, without many of the refinements of equipment available in civilian practice and sometimes without some of the equipment previously considered essential. Some of the officers and a great many of the technicians had had no previous interest in radiology, and many of them had little or no training in it. Frictions inevitably arose when hastily trained men were transferred into units completely alien to them. There was no denying that such experiences were traumatic. It required months of association before these men developed the pride in their units felt by personnel who had trained with them from the beginning.

Difficult though it might be, it was still possible to build up and maintain morale under these adverse circumstances. Success began with the realization by the chief of each radiology department that the responsibility for the efficient operation of the department was his and his alone. A department chief who realized his responsibility, and who made it clear to his staff that he did, inspired confidence. He increased their confidence by using his personnel in the positions in which they could serve with the greatest efficiency. He maintained a high level of radiologic productivity, at the same time refusing to be satisfied with anything less than a superior performance in terms of radiographs. His insistence on work of the highest quality engendered pride of performance in his staff, and their output and the quality of their work were correspondingly increased.

The reverse, of course, was also true. If the radiologist heading a department demonstrated a lack of interest in his work and made evident the sense of frustration that he sometimes inevitably felt, his own work and the work of his technicians alike suffered.

Colonel Hodes repeatedly noticed in his tours that the physical appearance of a department of radiology reflected the kind of discipline exercised by its chief, while film quality and artistry were evidence of the interest taken in their work by radiologic officers and technicians, as well as evidence of their respect for each other.

The Problem of Grade

While it was possible, by the means just described, to develop the team concept in X-ray technicians and raise their morale by instilling in them pride in their work and in their organization, one adverse influence on morale remained until the end of the war, the question of promotion in grade. The necessity of adherence to tables of organization harassed most of the chiefs of radiology in the theater and was a particular problem to those who were chiefs of these departments in affiliated hospitals. The affiliated hospitals that had been organized before 7 December 1941, in preparation for the war that seemed imminent, were instructed, after this date, to fill the roster of enlisted

personnel permitted by the tables of organization. The limitations of these tables created unfortunate situations. Technicians with greater skill and experience were frozen in a lower rank than others who knew little or nothing about X-ray technology but who rated a higher grade because their period of Army service had been longer. Technicians who had been X-ray technicians in civilian life could not be rewarded with the higher rating their competence deserved, a situation that was particularly unfortunate because dental technicians, who could be trained in a few weeks, received a higher rating than X-ray technicians with longer experience in civilian radiologic technology. Often, privates who knew more about X-ray technique than the sergeants who supervised them remained privates; the tables of organization established the ratio of privates to sergeants, and it was therefore not possible to reward a private for good work and initiative by recommending his promotion.

This difficulty, of course, was not confined to radiologic technicians. It was a problem in all specialties, and one that was never completely solved.

Section IV. Facilities

CLIMATIC AND ENVIRONMENTAL FACTORS

Because climate and environment exerted such influence in housing, equipment, general maintenance, and technical performance of all hospitals in the China-Burma-India theater, the description by its historian of the arrival of the 20th General Hospital at Margherita, Assam, in late March 1943, assumes peculiar significance (*4*). He wrote:

> The first view of the hospital was something never to be forgotten. We splashed out of the trucks into nearly six inches of soft slippery mud. It was a raw day, with leaden clouds and a driving rain. The hospital * * * consisted of a large polo field on which there were no buildings because it [would] be covered with water during the monsoon. Around this field on higher ground to the north were a group of bamboo bashas where American patients and our nurses were [subsequently] quartered. On the south was another group of bashas where the officers * * * were billeted * * *. The bashas were 20 by 80 feet with a 20-foot extension for latrines. Some of the floors were covered with bamboo matting, and others were dirt. The roofs were of palm leaves, and they leaked badly. There were no paths and what roads were present were deep with mud. There were no lights available and very few outlets for water.

This, then, was the setting in which the 20th General Hospital was to establish its X-Ray Department, a section of the hospital which required a firm foundation for the heavy, delicate apparatus with which its work was done and which also required protection from water, absence of humidity, and total lightproof construction.

On its arrival in Bombay, the 20th General Hospital was informed that its destination was to be Margherita, but it was inadequately prepared for what it was to encounter. Inquiries were made of the proper authorities as to whether materials to prepare for the monsoon would be needed, and assurances

were given that everything necessary would be available on location; nothing, therefore, was issued.

As a matter of fact, very little was available on location. The monsoon season had already begun. The site of the hospital was in the heart of the jungle. There was very little protection from the elements. Fortunately, only holding operations were going on at the time, and hospital personnel could devote almost total attention to clearing out the jungle and providing shelter for themselves and their equipment.

BASHAS

The bashas described by the historian of the 20th General Hospital were characteristic of the housing provided for the units which arrived earliest in the theater, and this type of housing was also used for some of the units which arrived later (fig. 238). Some hospitals which arrived early were even less fortunate. The 14th Evacuation Hospital, for instance, which set up at Ledo in 1943, reported that its first X-ray facilities were located "on the north side of the road, under tarpaulins" (*8*).

A basha is best described as a bamboo structure, roofed with thatch held in place by crosshatched bamboo poles, and with a life expectancy, due to termites, of not more than 18 months (*9*).

LATER HOUSING

In most, though not all, instances, bamboo bashas were replaced by bashas of the so-called pukka (or more substantial) construction. While the 73d Evacuation Hospital was in Ledo, its X-Ray Department was housed in a semipermanent building, but when the hospital was moved to Shingbwiyang, Burma, it was again housed in bamboo bashas, though the facilities were better than in most of the makeshift buildings used.

By 1944, however, most X-ray installations in the theater were housed in buildings that were at least semipermanent. Both the 69th and the 142d General Hospitals had comparatively new buildings, of brick, with brick partitions, and with wooden or concrete floors.

When the 73d Evacuation Hospital moved to Ledo, India, 15 months after its arrival in the theater, its X-ray facilities consisted of six rooms, including fluoroscopic and radiographic rooms, a darkroom, a storage room, and clerical and reading rooms. The arrangement was simple but adequate for the type and volume of work, and protection of personnel was good (p. 731). The outside covered porch was used as a waiting room and accommodated many ambulatory and litter patients (fig. 239). This was a particularly practical arrangement during the monsoon rains.

A completely blacked-out fluoroscopic room was constructed by using galvanized iron sheeting to cover the rear wall of the basha, to cover the windows and doors, and to roof the room to the 8-foot height of the brick

FIGURE 238.—Basha construction at 69th General Hospital, Ledo, India, 1944. A. Dental, Pharmacy, Laboratory, and X-Ray Building. B and C. Surgical wards.

walls. The room, which was satisfactory in all respects, was built by one of the X-ray technicians with native help.

The radiographic room was partly walled off, to a height of 7 to 8 feet, by the brick walls that were part of the protective system. Part of the back of the room was screened and the remainder was lined with Hessian cloth, for mosquito control as well as to insure cleanliness.

FIGURE 239.—Covered porch of 20th General Hospital X-Ray Department, Margherita, 1945. Patients are Japanese prisoners of war. A. Exterior view, showing construction of overhanging bamboo covered roof. B. View inside porch.

The darkroom consisted of a framework of boards lined with enough thicknesses of salvaged British tent cloth to achieve complete darkness. A small cement sink was installed in one corner, and a workbench was built along the wall facing the radiographic room. A leadlined pass box, constructed by the technicians, was built within the brick wall between the radiographic room and darkroom; the box opened just above the workbench in the darkroom.

The storage, reading, and clerical rooms, which were separated by bamboo walls, were partly screened and were lined with Hessian cloth.

A cement floor was laid in the darkroom and a wooden floor in the fluoroscopic room. In the other rooms, the floors were of red clay, firmly stamped down.

HOUSING INADEQUACIES

Some of the housing inadequacies encountered in the early months of operation militated against efficient radiologic performance. At the 20th General Hospital, for instance, both laboratory and X-ray facilities were crowded into one small, leaky basha, and the nursing, medical, and surgical offices were crowded into another. All records and desks had to be covered at night, and when it rained hard during the day, work sometimes had to be suspended. On one occasion, a fluoroscope was almost ruined when the tarpaulin which was used as a roof over the fluoroscopic room rotted and the unit was flooded with stagnant rainwater.

For a number of reasons, the transportation of patients to and from the X-Ray Department was often difficult. For one thing, because of the inces-

sant rain and the poor drainage, the ground was always muddy, and the mud was often inches deep. Then, because of the inflammable bamboo and thatch of which the bashas were constructed, regulations required that the wards be separated from each other by a minimum of 50 to 75 feet. Hospitals were therefore spread over wide areas. The easiest way to bring patients to the X-ray was by ambulance, and there were times at the 20th General Hospital when one ambulance, or even two, did nothing but shuttle patients to the department from scattered medical and surgical wards. There were also occasions when transportation was impossible and the patients had to be examined on the wards with field X-ray units.

The darkroom inherited by the 20th General Hospital from the organization which it succeeded had been planned by a surgeon, who happened to be very stout. In planning the maze to the darkroom, his own size was apparently his only consideration; he took no account of the fact that an entrance suitable for him made the baffle into the darkroom too large to serve as a light trap and also accounted for the fogging of films that was the hallmark of this special unit. To the trained radiologic eye, the trouble was immediately evident. Several strategically placed curtains easily corrected it and transformed a previously inadequate darkroom into a reasonably satisfactory one.

PROTECTION OF RADIOLOGIC PERSONNEL

In the China-Burma-India theater, as elsewhere, the greatest risks of exposure were in gastrointestinal fluoroscopy and foreign body localization. Various techniques for protection were used, beginning with the simple factor of distance. The length of the bashas and other buildings frequently made it possible to keep radiologic personnel at a safe distance from exposure. On the other hand, this was not always practical, particularly when space was tight. Whenever possible, however, all wiring was lengthened, to take advantage of the factor of distance for purposes of safety.

Entirely satisfactory protection was afforded by the brick walls employed at the 73d Evacuation Hospital, at Ledo, which were carefully planned while the building was under construction. Because it was immediately adjacent to a shallow ravine, no protection of the rear of the building was necessary. The other walls were constructed of brick, 12 inches thick, and extended 8 feet above floor level.

When the Radiology Department of the 73d Evacuation Hospital was housed in a basha in Shingbwiyang, Burma, the same type of protective brick walls was employed. In addition, a brick wall 7 feet high, 3 feet wide, and 12 inches thick, was erected in the radiographic room, adjoining the X-ray table, to serve as a protective screen for the technicians. Like the walls in the building at Ledo, it was found satisfactorily protective against radiation.

The 142d General Hospital, which occupied a new building in Calcutta, had mobile lead screens, and even the doors between the various rooms were leadlined.

FIGURE 240.—X-ray room, 20th General Hospital. Note sandbags, held in place by bamboo poles, for protection of personnel against radiation.

During its first year in the theater, the 20th General Hospital, after trials of other improvisations, found that sandbags, held in place by bamboo poles (fig. 240), furnished excellent protection against radiation, just as certain hospitals in the Pacific had found them (p. 531). All X-ray personnel wore small pieces of X-ray film in envelopes at all times, to test the safety of this method.

While X-ray technicians had excellent protection by these various methods, protection of the fluoroscopist and his assistants was more difficult. The X-ray tube head was not well shielded, and during fluoroscopy, therefore, considerable exposure of the lower extremities could take place. It was thus important that all lead shielding, including lead aprons, reach well below the knees of the examiner. The danger was recognized in the Zone of Interior and a leaded rubber shield for the tube head was devised by Colonel de Lorimier and his associates (*10*) to cut down radiation to the tolerance level, but it was never received in the China-Burma-India theater.

At the 20th General Hospital, two lead aprons were used to protect the fluoroscopist, one overlapping the other. In this manner, the limbs were protected well below the knees. The same plan was used at the 73d General Hospital. Later, the principle was effectively applied in the development of a simple protective lead shield (fig. 241), which could be used with the field unit and which afforded the examiner the protection against scattered radiation so absolutely essential for the protection of his lower limbs (*11*). The

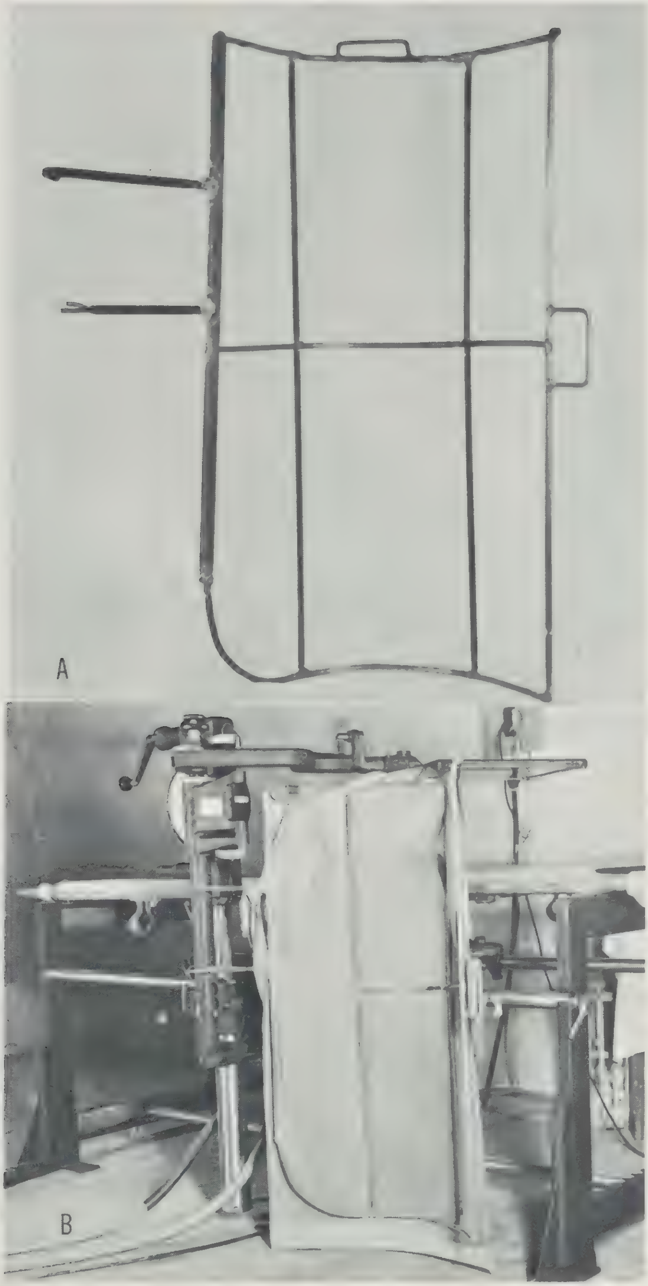

FIGURE 241.—Protective device used in erect fluoroscopy with Army field unit, at 20th General Hospital. A. Frame constructed of scrap metal. B. Rubber aprons attached to frame. Note that this device protects the feet as well as the rest of the body.

frame was made of pieces of scrap metal, welded together. One lead-impregnated apron was hung by straps from the top of the frame, the straps being so adjusted that the apron touched the floor. A second apron was inverted and clamped against the top of the frame. Its straps were fastened to the sides of the frame. This device, which protected the technician from the level of the fluoroscopy screen to the floor, was simple and portable and could be constructed easily by ordnance personnel.

A protective chair improvised at the 20th General Hospital for vertical fluoroscopy had a partial lead backing, with a rubber apron extending to the floor. The chair was on rollers, and the fluoroscopist working in it was completely protected.

These cumbersome protective measures should not have been necessary and would not have been if some sort of protective shield had been an integral part of radiologic equipment.

Protective measures were generally satisfactory, but in spite of the precautions taken, two technicians at the 20th General Hospital caused some concern when their hemoglobin fell to about 75 percent. Although the chiefs of the medical and laboratory services did not believe the drop was of any significance, since the total white blood cell count and the differential and reticulocyte count remained within normal range, these men were permanently removed from further possible exposure to radiation and assigned to clerical duties. Within a month, their blood levels had returned to normal, and when they were last heard from, 15 years after this episode, both were perfectly well.

Section V. Equipment and Supplies

PRIORITIES

Radiologists in the theater were aware from the outset that there would be major difficulties in securing equipment and supplies. They could not operate without them, but they recognized the initial order of priorities as fair because for the first months of operation the hospital load consisted chiefly of patients with malaria, dysentery, and similar diseases.

Priorities were as follows:

1. Items that had to do with the actual building of the Ledo Road, which was being constructed to connect with the Burma Road. Engineering materials had first priority in transportation from any port of entry into Assam, to which the only routes of supply were by narrow gage railroad from Calcutta or by air.
2. Food.
3. Combat materiel.
4. Medicines.
5. X-ray supplies.

FIGURE 242.—Deterioration of cable housing with breakdown of insulation in the terminal.

STANDARD EQUIPMENT

Except for some 200-ma. (milliampere) units in Calcutta, Karāchi, and Margherita, the only equipment available in the China-Burma-India theater was the 30-ma. standard issue (Picker) field portable unit. In spite of the pervading dampness and the fact that the generator was frequently rained on, there was general agreement that this was an extremely efficient piece of apparatus.

Comments on the larger pieces of equipment were less favorable. About a year after the 20th General Hospital had arrived in the theater, its Radiology Department received Westinghouse and Philips units (both 2-tube, 200-ma.). The Philips unit could never be used because the transformer was broken when it was received. Its X-ray table was modified for use with the Picker mobile unit. The Westinghouse unit functioned well until moisture in the walls of the shockproof cables put it out of action (fig. 242).

So far as is known, high tension X-ray cables seldom failed because of human error during the 3 years during which X-ray service was provided in the China-Burma-India theater. Radiologists, however, lived in constant anxiety that this might happen, for there were no replacements. Numerous protective measures were used: The equipment was kept covered, the cables were taped (fig. 243), and grease was used in the cable wells. In spite of all efforts, high-tension cables did break down occasionally, usually in the wells.

FIGURE 243.—Closeup view of cable, showing use of protective tape. One cable is totally covered, with the second only half covered.

Most hospital reports mentioned no difficulties with electric current. The usual source of power, according to the 1944 and 1945 annual reports of the 142d General Hospital (*6*), was the 27-kva. Buda Diesel generator or the 25-kv. generator of the type used by the 20th General Hospital.

All things considered, it is remarkable how well the field unit and accessory equipment withstood extremely adverse conditions (*12*). Even the control panels proved entirely trustworthy. Nonetheless, it would have been comforting to know that, if units should fail, replacements would be available. Priorities always prevented that assurance.

Breakage

Breakage during transportation, undoubtedly because of rough handling, was always a serious problem, particularly in Pacific Ocean Areas (p. 627), during changes of station. It occurred equally in equipment packed in wooden crates and in equipment (the fluoroscopic screen and the control panel for the portable field table) packaged individually in special Army trunks.

Soon after the 20th General Hospital had arrived in Assam, the Department of Radiology was delighted to receive a number of crates containing X-ray equipment to supplement its single Picker field unit. The crates had originally been shipped to Rangoon and then, when Burma fell, had been

transshipped to Calcutta and Bombay. The units were small and light, with self-rectified heads.

The pleasure of the radiologic personnel was short lived. It was necessary only to pick up a box to realize that the X-ray tubes were broken. When the boxes were opened, not a single tube was found intact. Investigation revealed that, when the crates had been unloaded in Bombay and then in Calcutta, they had been dumped on the docks, with no regard at all for their fragile contents.

THE DARKROOM AND ITS EQUIPMENT

Theoretically, the portable darkroom designed for use in the field was an excellent piece of equipment. It was made of cloth, on a metal frame, and it was easily assembled. Apparently, however, it had not been tested under tropical conditions, and it did not meet the needs of the China-Burma-India theater. During the monsoon season, darkrooms did not last more than 3 to 6 months. Their cloth roofs acted as water traps, which could be emptied only by pushing up on them from inside the tent. There was little to be done to lengthen the life of these darkrooms; if the cloth did not rot, the accumulated water became stagnant, or both situations developed.

As in the European theater (p. 377), the small ventilating fan provided for the darkroom was totally ineffectual; it did little more than make a great deal of noise.

Developing Tank

The Army developing tank, which could be used as soon as electricity was available, gave excellent service for about a year. During the second year of operation, corrosion due to humidity caused breakdowns, particularly of the cooling units. To secure replacements was not a simple matter.

Water

Water for processing films was obtained with difficulty. There were no facilities for collecting rainwater or preparing distilled water. River water, even when boiled and filtered, was not satisfactory. Almost all of the water available was either so heavily chlorinated or contained so much organic matter that normal developing processes were interfered with. The water used at the 20th General Hospital was secured, all through its tour of duty in the theater, from the well of a neighboring tea planter. Colonel Hodes, with Capt. (later Maj) George P. Keefer, MC, made a special report on the difficulties of processing films with the water supply available in the theater and the oxidation of solutions caused by water pollution (*12*) (fig. 244).

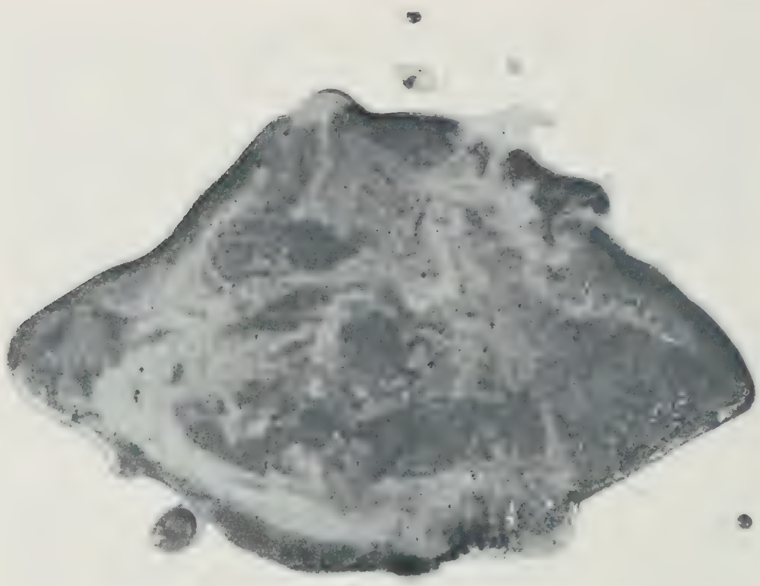

FIGURE 244.—Scum scraped from surface of developing solution.

CASSETTES AND SCREENS

All radiologic departments in the China-Burma-India theater had difficulty in obtaining cassettes of the proper size. Some departments had only a single size, usually 14 by 17 inches. With films in short supply, as they usually were, it would have been inexcusably wasteful to use such a size unnecessarily, and it was the general practice to cut the films down to the desired size and mark the cassettes accordingly. In some hospitals that had only 14- by 17-inch cassettes, the only films available were 8 by 10 or 10 by 12 inches. It required considerable ingenuity to use these films for a chest examination in 14- by 17-inch cassettes. Obviously, the film would be of diagnostic value only if the pieces were correctly fitted together.

Even when the sizes of cassette and film coincided, the heat, humidity, rain, and monsoons created problems. In spite of filtration and settling tanks used for solutions, enough silt still remained to clog surface drains, so that sediment formed a mud-line scum on the screens. Constant vigilance was also necessary to prevent perspiration from marring the films and cassette screens. A single drop caused an imprint on the screen or film emulsion which could not be eradicated. Mold was a constant problem (fig. 245).

The most serious damage to cassettes occurred when ever-present moisture caused the emulsion on the film to stick to the emulsion on the screen, with permanent scarring of the screen (fig. 246). To avoid such damage, technicians were trained to open the cassette for only a few inches while they

FIGURE 245.—Examples of mold on anteroposterior roentgenograms of chest.

were removing the film and reloading the cassette. They were also trained to cover their wrists and forearms with paper or cloth to absorb perspiration.

Little damage was sustained by 8- by 10-inch and 10- by 12-inch cassettes, but the 14- by 17-inch size had to be remounted at least twice a year because of the bulging of the Bakelite face caused by moisture. In spite of the most conscientious care, more than half of the cassettes originally in use had to be replaced.

At the 20th General Hospital, because dehydrating substances were not available, cassettes were stored in a well-ventilated wooden box, underneath which were 25-watt electric bulbs (fig. 247). This simple method proved quite effective.

Not infrequently, blebs about 2 millimeters thick, and ranging in diameter from 2 or 3 millimeters to several centimeters, developed on the surface of the screens. It was never determined whether they were caused by perspiration or humidity.

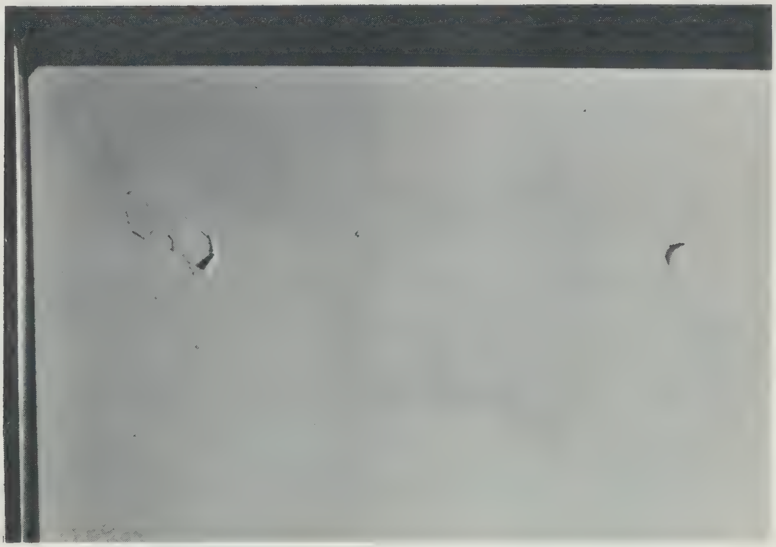

FIGURE 246.—Blistering of screen of cassette and peeling of emulsion from its surface.

OTHER EQUIPMENT

Other equipment, including grids (fig. 248) and fluoroscopic screens (fig. 249), also suffered from the humidity.

FILMS

During the early months X-ray departments were operating in the China-Burma-India theater, films were invariably found fogged. At first, it was assumed that the films were old and that their expiration dates had been passed. With few exceptions, however, all were well within the limiting dates. It therefore had to be assumed that the films had not been properly packed; that they had not been stored upright, to prevent damage from pressure; and that there had been no attempt to store them in cool places, to protect them from the ravages of tropical heat.

This situation continued for a considerable time. For many months, there was no source in the theater from which satisfactory films could be procured, and in spite of the volume of correspondence on the subject sent through proper channels, it was well over a year before films arrived properly packed for delivery to, and use in, a tropical environment.

Even proper packing, however, did not end the difficulties. In the hot, humid atmosphere of Burma and India, the gelatin on the films provided an excellent medium for the growth of various fungi, and a grayish-green mold

FIGURE 247.—Drier improvised at 20th General Hospital for storage of cassettes. Heat is provided by electric light bulbs inside the box.

very often appeared in patches, particularly on exposed and processed films. Rapid drying and the use of dry containers retarded the development of mold, but did not entirely prevent it. At the 20th General Hospital, it was found that its appearance could sometimes be forestalled if the processed film was immersed in 5 percent formaldehyde for 1 minute, after which it was allowed to dry slowly in air.

The 44th Field Hospital Department of Radiology reported that high temperatures had so affected its films that the emulsion was sometimes loosened and, when the films were processed, it washed off the base completely (*13*). This hospital also reported that some of its films, in addition to being outdated and of poor quality, had markings on them that indicated their exposure to static electricity during shipment.

Other Processing Problems

Some departments of radiology made no mention in their reports of drying facilities and the effect of delayed drying on films. Those which did invariably stated that the high humidity slowed drying. Some hospitals never achieved a satisfactory technique. The 69th General Hospital used a wooden rack to drain excess water off the films before they were put into the drier and found that this practice expedited the process. The 20th General Hospital developed its own drier, a hybrid combination of a stove and the

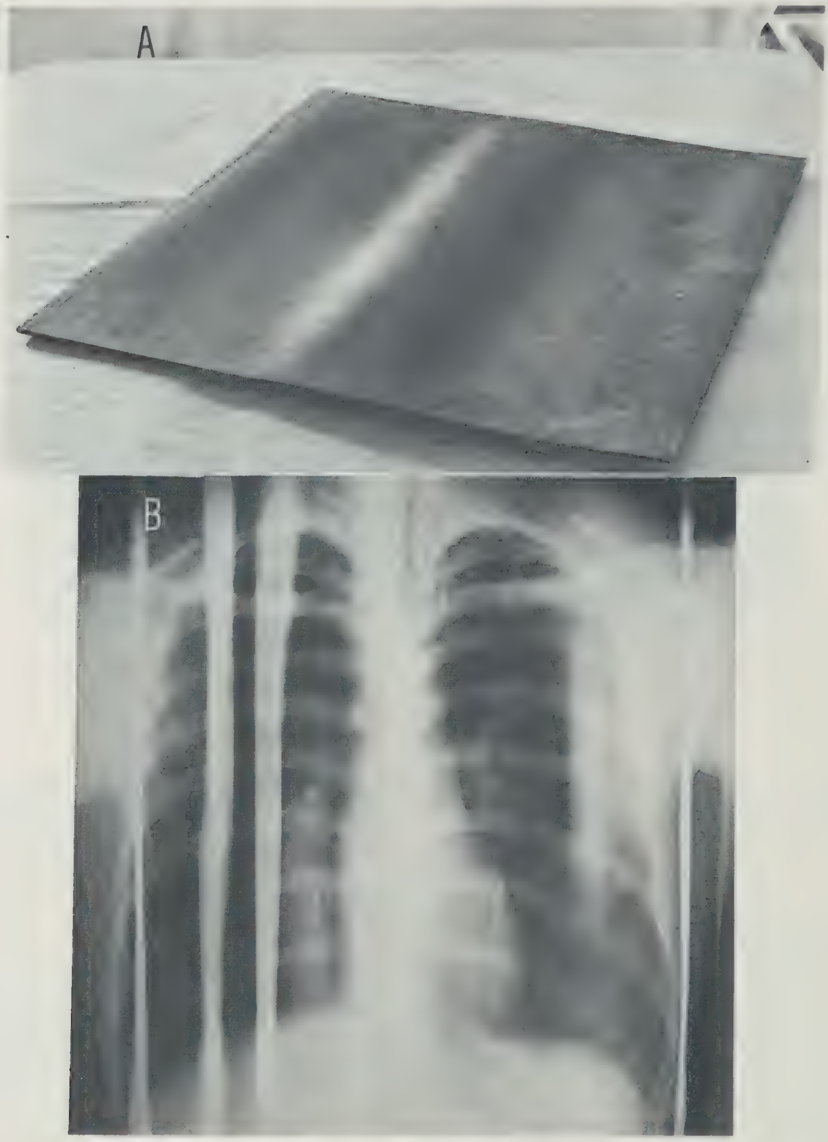

FIGURE 248.—Effect of humidity on equipment and radiographs. A. Warping of grid as result of moisture. B. Anteroposterior roentgenogram of chest, showing effect of warping of grid.

standard drying racks. At first, the drying racks were situated over a Coleman burner, which made them look like baking ovens; later, electric bulbs were used as the source of heat. This device was a source of great amusement to everyone and was shown to all visitors, including Gen. (later Field Marshal) Sir Archibald Wavell when he visited the area. It was highly effective, however, in spite of rain, monsoon, and constant humidity.

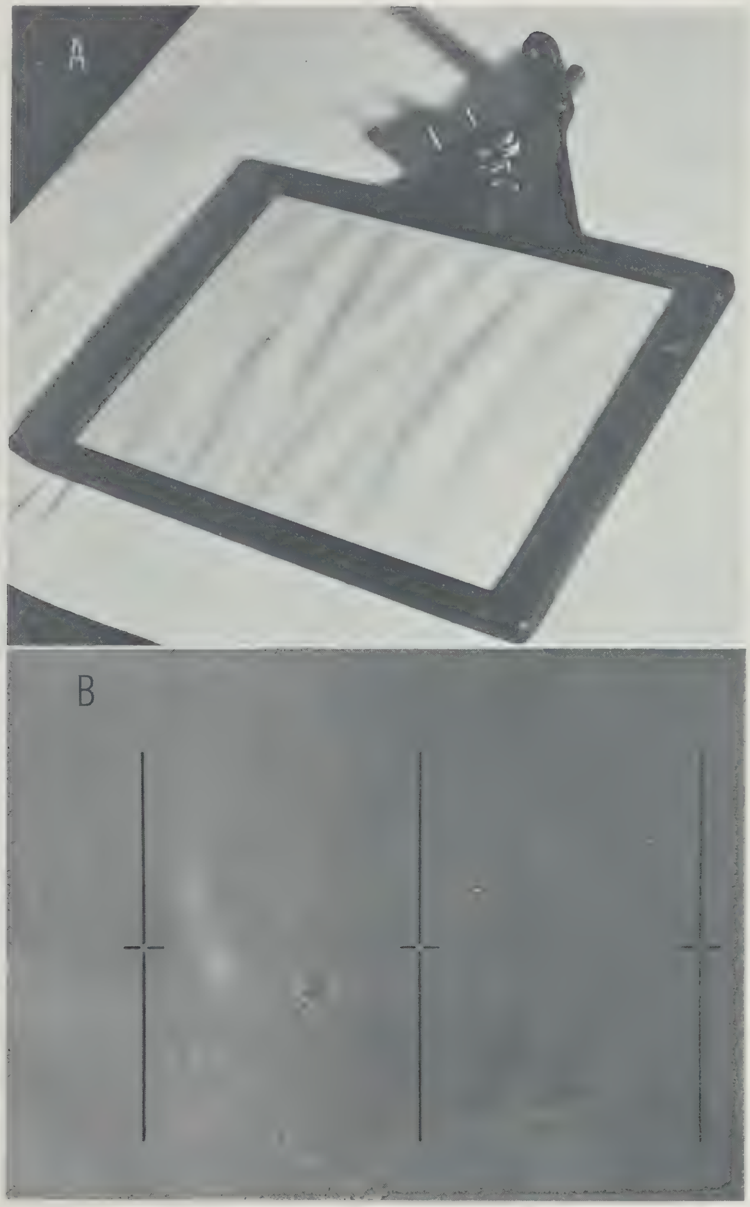

FIGURE 249.—Damage to fluoroscopic equipment from constant humidity. A. Warping and destruction of fluoroscopic screen. B. Accumulated droplets of moisture between fluoroscopic screen and overlying lead glass.

Chemicals for developing X-ray films provided a constant problem. They were often difficult to obtain and had to be secured from British sources. The British supply unfortunately proved inferior; films developed with them were of correspondingly inferior quality.

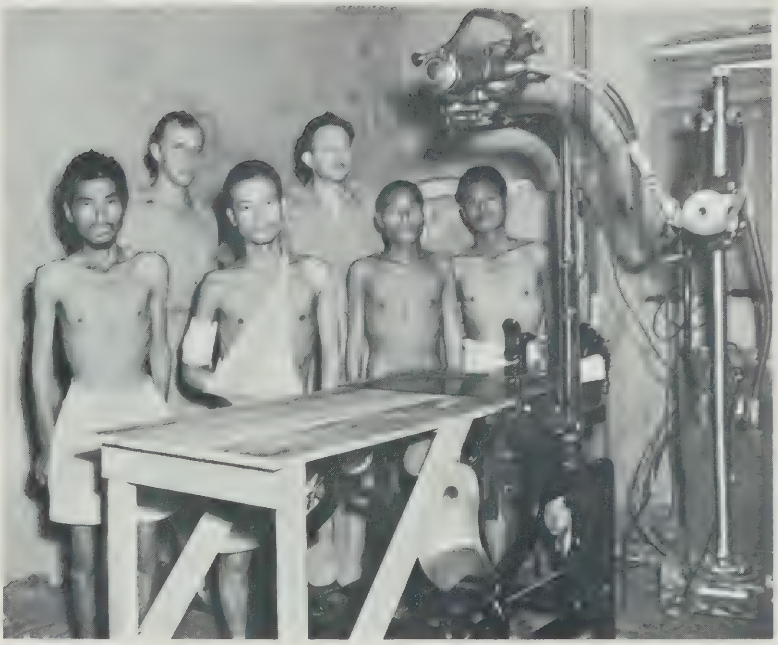

FIGURE 250.—Improvised horizontal X-ray table used with Army portable field unit by 20th General Hospital. Japanese prisoners of war are waiting for examination. Note protective taping of cables.

Several hospitals mentioned using ice to cool their solutions, but even this arrangement, according to the 1944 report of the 14th Evacuation Hospital, was far from satisfactory (*8*). The air-conditioning unit requisitioned in 1945 by the 142d General Hospital was never received, though the justification for it was carefully spelled out (*6*).

IMPROVISATIONS

Numerous improvisations were employed, in addition to those already mentioned:

Personnel of the 69th General Hospital constructed a cabinet, with calcium chloride, which was frequently changed, in the bottom, to keep their intensifying and fluoroscopic screens dry (*7*).

At the 44th Field Hospital, technicians were protected by a booth constructed of pieces of corrugated tin secured from roofs of some adjacent wrecked buildings (*13*). It effectively lessened the risk of overexposure from scattered radiation and also from secondary radiation emanating from patients.

The 20th General Hospital improvised a horizontal X-ray table to be used with the Army portable field unit (fig. 250); an erect fluoroscopic table

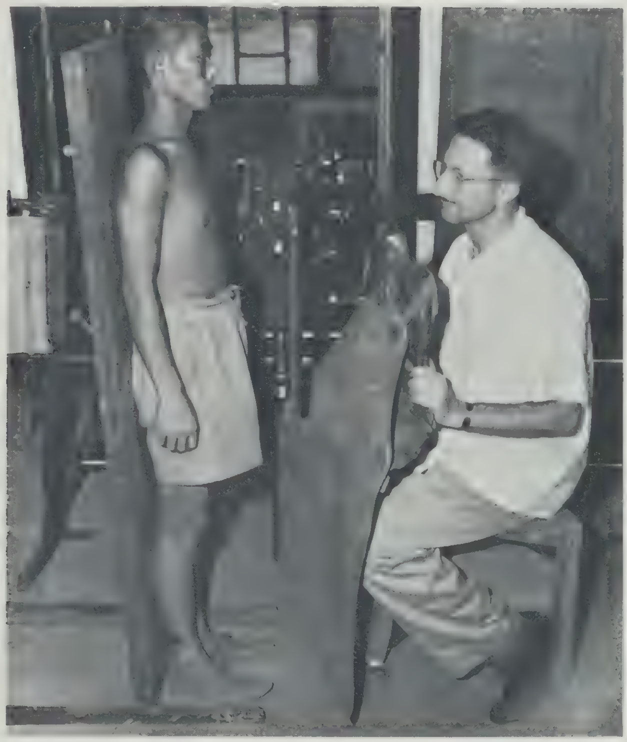

FIGURE 251.—Improvised chair and improvised erect table used for fluoroscopy, with portable field unit, by 20th General Hospital.

and a chair for fluoroscopist (fig. 251); a special fluoroscopic technique, to compensate for the absence of a darkroom (fig. 252); and metal tips (copper or steel) for enema tips. These tips could be constructed by any heavy ordance outfit, which could shape them on a lathe.

Identification of Films

The 20th General Hospital Department of Radiology also devised a simple and effective light box for the identification of films (*14*). The box was constructed of materials available at any military installation. The printing device was built into an ordinary ward bedside table, in the top of which a slot 1¼ by 3 inches had been cut, to permit transmission of light from a light-tight compartment below the top of the table. Two wooden guide strips, placed at right angles to each other, assured that the protected portion of the film would coincide exactly with the slot in the top of the table. The lid that covered the slot was made light tight by lining it with sponge rubber, which had the additional purpose of pressing the film against

FIGURE 252.—Improvised fluoroscopic technique used at 20th General Hospital. A. Preparation for examination. Fluoroscopist (Lieutenant Colonel Hodes) holds pup tent with which he will secure sufficient darkness for the examination. B. Examination of ambulatory patient. The spots on this picture and the preceding pictures are caused by mold on the emulsion of the negatives. C. Examination of litter patient by improvised fluoroscopic technique. Note protective sandbags.

the card. The source of light was variable: A 150-watt bulb was adequate, but an ordinary battery-powered flashlight was equally satisfactory. Somewhat similar devices were used in other theaters.

Related to the accurate identification of films was the great importance

of reports of the roentgenographs. It was seldom an easy matter to find an enlisted man with enough knowledge of shorthand and typing to take dictation from the radiologists and to type the reports. It was even harder to find a man with the educational background necessary to do the work satisfactorily. Errors in spelling and typing made constant vigilance mandatory. Doublechecking the reports from this standpoint often caused delays in reporting.[3]

The form sheets used in the European theater provided one method of obviating these difficulties. Simple checklists also saved considerable time.

REPAIRS AND REPLACEMENTS

Some departments of radiology were hindered in their initial operations in the theater by lack of essential pieces of equipment. The 14th Evacuation Hospital, for instance, for several weeks after it was set up, had no film developing tank nor could one be obtained (*8*).

The initial equipment, even if it was complete, was sufficient only for the essentials; there was no excess. This was unfortunate, for equipment simply did not stand up well in the hot, humid climate of Burma and India (*12*). As the radiologist at the 14th Evacuation Hospital noted in his 1944 report (*8*): "* * * Once again it was demonstrated that if any practical use is to be made of the modality of X-ray in a tropical country in monsoon weather, there must be additional equipment to defeat the twin hazards of heat and moisture."

On the other hand, the Department of Radiology at the 142d General Hospital had few difficulties because it was located near a medical supply depot in Calcutta (*6*).

All the radiologists in the theater, no matter to what type of hospital they were attached, reported the urgent need for a source of replacements and for some means of obtaining repairs. Requests for both replacements and repairs were numerous. Instructions for requisitioning them were clear, but those responsible for filling the requests evidently did not realize their urgency, and the X-ray departments would have fared badly except for the assistance they received from other groups, particularly maintenance units.

Poor communications and poor liaison within the theater were responsible for many delays in repairs. Communications were particularly poor between forward echelons and headquarters in Delhi and in Karāchi. A typical example was the difficulty experienced by the 20th General Hospital in having its Philips unit repaired, at a time when it was needed very badly.

The hospital staff learned that a civilian representative of Westinghouse International had just been flown to Bombay to repair essential therapy equipment at the Tata Memorial Hospital, a large civilian institution for the

[3] The 20th General Hospital was remarkably fortunate in respect to its records: Captain Keefer was as competent a typist as he was a radiologist, and its reports could therefore be completed and dispatched correctly and without delay.

treatment of cancer. He apparently had been informed of the difficulties the 20th General Hospital was experiencing with the Philips unit and had been instructed to get in touch with the chief of radiology at that hospital. Before he left for the United States, he called on Colonel Tamraz at New Delhi, where he learned that he was being sought everywhere because of continued requests for his services by Colonel Hodes. At any rate, he was finally flown to Assam, where, after 2 weeks of work, he was obliged to admit that he could not put the unit into satisfactory working order because of the lack of essential replacement parts.

It should be said in conclusion, however, that in spite of such examples of inefficiency, and in spite of shortages, inadequate equipment, technical difficulties, polluted water, poor communications, and the ever-present factors of heat and dampness, the number of X-ray examinations made in the China-Burma-India theater and their clinical value are a testimony to the efficiency with which departments of radiology conducted their operations.

Section VI. Clinical Considerations

Combat-Incurred Injuries

HEAD INJURIES

Combat-incurred injuries in the China-Burma-India theater in general did not differ from those encountered in other theaters of operations. Gunshot wounds of the head, however, because of the type of fighting in the theater, were frequent and were, of course, extremely important because of possible complicating chronic cerebral disease and the abnormalities that might result later.

One such injury is worth reporting because of the unusual complications, interstitial emphysema and pulmonary collapse, which were associated with the skull fracture (*15*):

Case 1.—The patient, a Chinese, was brought to the hospital unconscious after sustaining a gunshot wound of the head. From the time he was admitted until his death, some 5 hours later, he experienced marked respiratory embarrassment. His respirations were so rapid, a satisfactory chest examination was impossible. Foamy mucus was blown out of the mouth with each expiration.

Direct examination of the nasopharynx revealed intense swelling of the mucous membrane, interstitial hemorrhage, and bloody mucus in the roof of the cavity.

Permission for post mortem examination was not granted,[4] but roentgenologic examination immediately after death showed pulmonary collapse and interstitial emphysema.

Skull fractures of the kind this patient sustained, which extend through the petrous pyramids and the basilar portion of the occipital bone, are easily

[4] According to the 1944 report of the 73d Evacuation Hospital, autopsies were difficult to obtain in Chinese patients because of the general racial belief that all scars and wounds present at the time of death disappear post mortem, while those which occur after death remain in situ (*5*).

demonstrated radiographically. Although in this case a tear in the membrane lining the nasopharynx was not actually demonstrated, it seemed reasonable to attribute the nasoscopic findings observed to the basilar fractures, which were probably compound. Such a tear would open fascial planes, along which interstitial air could travel to enter the posterior mediastinum. It was not determined whether the partial pulmonary collapse was caused by a pleural tear, which allowed air in the posterior mediastinum to enter the pleural cavity, or whether the air, under pressure, stripped the parietal pleura from the chest wall.

Encephalography

As a means of fully investigating the consequences of head injuries, the radiologists at the 20th General Hospital enlisted the cooperation of the neurosurgeon on the staff, Lt. Col. Robert A. Groff, MC, to study one such case by encephalography, 36 hours after wounding. The method seemed valuable, and since there were no untoward results in the first case, 18 other patients were similarly examined, from 36 hours to 86 days after injury, with special attention to the development of such complications as porencephaly, shifts of the brain, and hydrocephalus, all of which tend to develop rapidly.

The results of the study were submitted to the Office of The Surgeon General, with request for permission to publish the article. The permission was refused, with the comment that the procedure was not considered wise in combat casualties. It was apparently overlooked that the personnel engaged in this study were both mature and certified in their specialties.

The subjects for the investigation were carefully selected, the possible risk of infection being borne in mind and no patient being included whose wound was thought to be contaminated. All those studied were in excellent physical condition and presented no evidence of increased intracranial pressure, even when neurologic signs of brain damage were present.

Nembutal (pentobarbital sodium) was given an hour before the examination. The original dosage of 6 to 9 grains was gradually reduced to 3 grains in order to obtain better cooperation from the patient.

The entire procedure was carried out in the Department of Radiology. The cerebrospinal fluid system was drained with the patient erect. During the first week after injury, blood was always present in the fluid, in varying concentrations. Later examinations, several weeks after injury, usually revealed no blood elements. Every effort was made to drain the system completely; the amount of fluid withdrawn varied from 80 to 180 cubic centimeters. Manometric readings were not taken routinely; when they were obtained, they revealed no increase in spinal fluid pressure.

The technique followed the standard method for diagnostic air studies, and the reactions were no more than observed with them. Intracranial hemorrhage, convulsions, infection, and other serious reactions did not occur.

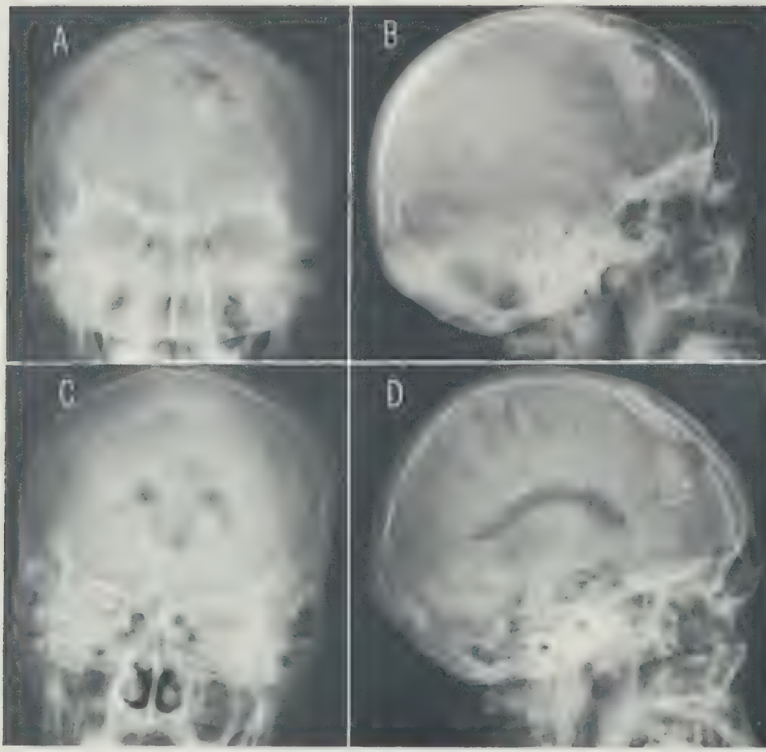

FIGURE 253 (case 2).—Encephalographic study of head injury. A. Posteroanterior roentgenogram, showing depressed fracture of left frontal region. B. Lateral roentgenogram, showing depressed fragments of bone. C. Pneumoencephalogram, showing no shift of midline structures. D. Lateral projection, showing obliteration of subarachnoid markings in frontal lobe only.

The practice of selecting patients with great care was continued, and the lack of complications throughout the study can probably be attributed to that precaution.

Sample case histories:

Case 2 (fig. 253).—This casualty was admitted to the 20th General Hospital 2 days after he had sustained a penetrating wound, 10 cm. long, of the cranial cavity, located just within the hairline and extending from the midline laterally to the left. The wound, which looked clean, had been closed in a forward hospital by interrupted dermal sutures. There was no neurologic evidence of brain damage. The blood pressure was 100/80 mm. Hg, the temperature 100° F., the pulse 98, and the respiration 20.

Routine roentgenograms of the skull revealed a defect 3 by 6 cm. in the left frontal bone, to the left of the sagittal suture and anterior to the coronal suture. There were numerous bone fragments in the left anterior fossa, 5 cm. from the bone defect. Several small fragments were lodged around the fracture site.

Encephalograms, 4 days after wounding, showed normal third and fourth ventricles, normal basal cisternae, and no shift of the midline structures. The subarachnoid mark-

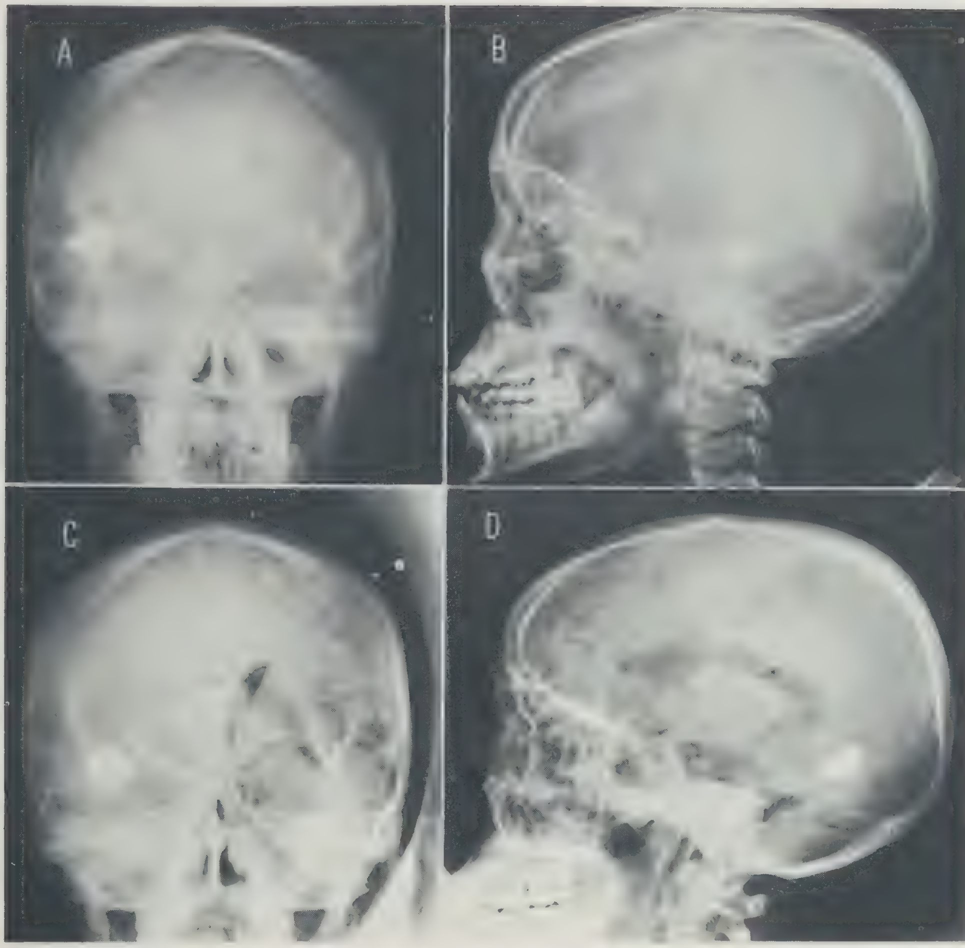

FIGURE 254 (case 3).—Encephalographic study of head injury. A. Posteroanterior roentgenogram, showing large shell fragment in right hemisphere of brain. B. Lateral roentgenogram with better localization of fragment. C. Encephalogram, showing shift of midline structures to left with obliteration of subarachnoid markings and encroachment upon lateral ventricle of affected hemisphere. D. Lateral projection. The difference in projection explains the difference in the appearance of the shell fragment in views B and D.

ings were essentially normal in the parietal and occipital areas, but were entirely obliterated over both frontal lobes. The lateral ventricles were about normal in size, but the left anterior horn was slightly depressed.

At operation, 22 days after injury, the bony defect was found to consist of two separate openings, one 1 cm., and the other 4 cm., in diameter. Between the openings was a depressed fragment of bone. The dura beneath the large defect was lacerated. Degenerated brain substance and many bone fragments were removed from the underlying brain, together with material that looked like purulent exudate but that was found sterile on culture. After debridement, a cavity measuring 3.5 cm. in diameter remained.

Case 3 (fig. 254).—This casualty was admitted to the 20th General Hospital, 3

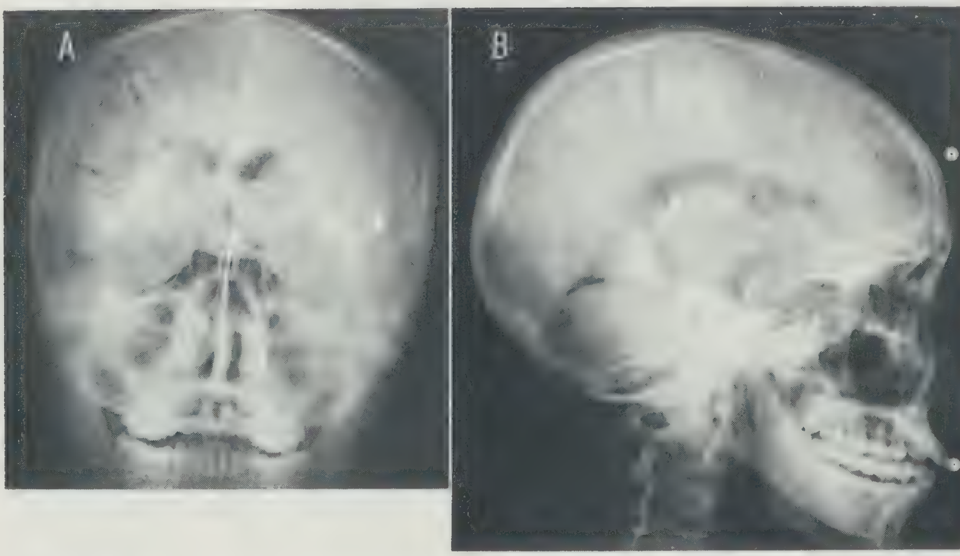

FIGURE 255 (case 4).—Encephalographic study of penetrating wound of left parietal bone. A. Encephalogram, showing shell fragment in left parietotemporal region with slight shift of midline structures to right. Note absence of subarachnoid channels over affected hemisphere. B. Lateral projection.

days after he had sustained a penetrating wound of the cranial cavity 2 cm. in diameter and situated over the inner margin of the right eyebrow. The right eye was blind. Neurologic examination revealed nothing abnormal. The blood pressure was 122/68 mm. Hg, the temperature 99° F., the pulse 64, and the respiration 18.

Routine radiograms of the head revealed a comminuted fracture of the right supraorbital ridge, involving the floor of the right anterior fossa and the right frontal sinus. Multiple bone fragments were driven upward into the base of the right frontal lobe. A large shell fragment measuring 15 by 20 by 20 mm. was observed in the right parietal lobe, 9 cm. from its point of entry.

Encephalography, 5 days after injury, revealed the midline structures shifted to the left. The subarachnoid channels over the right hemisphere were not visualized; those in the parasagittal portion of the left cerebrum were partly obliterated. The right lateral ventricle was somewhat encroached on by the injured side and was shifted away from the injured side of the brain; its anterior horn was notably distorted. The third ventricle was also shifted toward the left. The fourth ventricle and basal cisternae were normal.

At operation, 6 days after injury, the bone defect was found to measure 2 cm. in diameter. The dural defect measured about 3 centimeters. Macerated brain, herniating through both defects, was removed by suction. The resulting cavity was about 3 cm. in diameter and 4 cm. deep.

Case 4 (fig. 255).—This casualty was admitted to the 20th General Hospital 5 days after he had sustained a clean wound, 2 cm. long, in the left parietal region, 3.5 cm. to the left of the midline. Positive neurologic signs included a partial motor aphasia, plus minor sensory changes on the right side of the body. The blood pressure was 98/72 mm. Hg, the temperature 98.2° F., the pulse 78 and the respiration 18.

Routine radiograms of the skull revealed a bone defect, 1 cm. in diameter, and depressed about 0.5 cm., in the middle of the left parietal bone. The shell fragment,

5 by 4 by 3 mm., lay near the base of the left parietal lobe 6 cm. from the wound of entry.

Encephalograms, 7 days after wounding, revealed the midline structures slightly shifted to the right of the midline. The subarachnoid markings over the entire left cerebral hemisphere were poorly visualized; those over the uninjured right hemisphere were normal. The left lateral ventricle was slightly dilated, but the right lateral ventricle and the third and fourth ventricles were normal. The cisterna chiasmatica was poorly outlined, but the cisterna interpeduncularis and the cisterna pontis were clearly outlined and normal. A small amount of subtentorial air was present.

At operation, 30 days after injury, the defect in the parietal bone was found to be 1 cm. in diameter. A bone fragment, driven into the dural defect, acted as a plug. The dura was tense. When the depressed bone fragment was removed, thick, dark, liquefied blood and degenerated brain oozed out of the opening in the dura. After devitalized brain had been removed, the residual cavity in the lower portion of the parietal lobe was 2.5 cm. in diameter. The shell fragment was left in situ.

Case 5 (fig. 256).—This casualty was admitted to the 20th General Hospital the day after he had sustained a clean linear wound, 10 cm. in length, located just above the right ear and extending posteriorly. It had been closed by four interrupted dermal sutures. There were no abnormal neurologic signs. The blood pressure was 115/85 mm. Hg, the temperature 98° F., the pulse 94, and the respiration 22.

Routine roentgenograms of the skull revealed a 3-cm. bone defect located 2.5 cm. above, and slightly behind, the right ear. Bone fragments were driven 5 cm. into the right temporal lobe.

Encephalographic studies, 8 days after injury, revealed displacement of the midline structures upward and toward the left. The subarachnoid pathways over the injured right hemisphere were not visualized; those over the left cerebrum appeared normal. The right lateral ventricle was considerably encroached upon by, and seemed smaller than, the left, which was essentially normal. A small amount of air was observed in the posterior portion of the third ventricle. The fourth ventricle was not visualized. A large porencephalic cyst occupied part of the right temporal lobe in the region of the island of Reil. The cisterna chiasmatic was normal. The cisterna interpeduncularis and the cisterna pontis were not well visualized, although the cerebrospinal system had presumably been thoroughly drained.

At operation, 37 days after injury, the cranial defect and the underlying dural defect measured 3 by 2 centimeters. Degenerated brain, which had the appearance of purulent exudate, and depressed bone fragments were removed from the temporal lobe. One bone fragment had penetrated the lateral sinus; the defect was repaired.

Comment.—This study was undertaken with three objectives:

1. To ascertain whether it was possible to determine, from survey films of the head, how much brain damage had been produced by an injury. This objective was not attained. It was found impossible to predict the character of the intracranial changes from clinical findings and routine roentgenograms, probably because almost nothing was known concerning the circumstances of injury or the forces exerted upon the head by the impact of the missile. The impression was gained, however, that extensive gunshot injuries of the face that extended into the cranium did not produce as much damage as was produced by injuries to the vault itself.

2. To determine whether changes in the brain after injury were diffuse or were confined to the field of the injury. It had been observed that patients operated on for gunshot wounds of the cranial cavity often did less well after operation than might have been expected from the appearance of the brain at

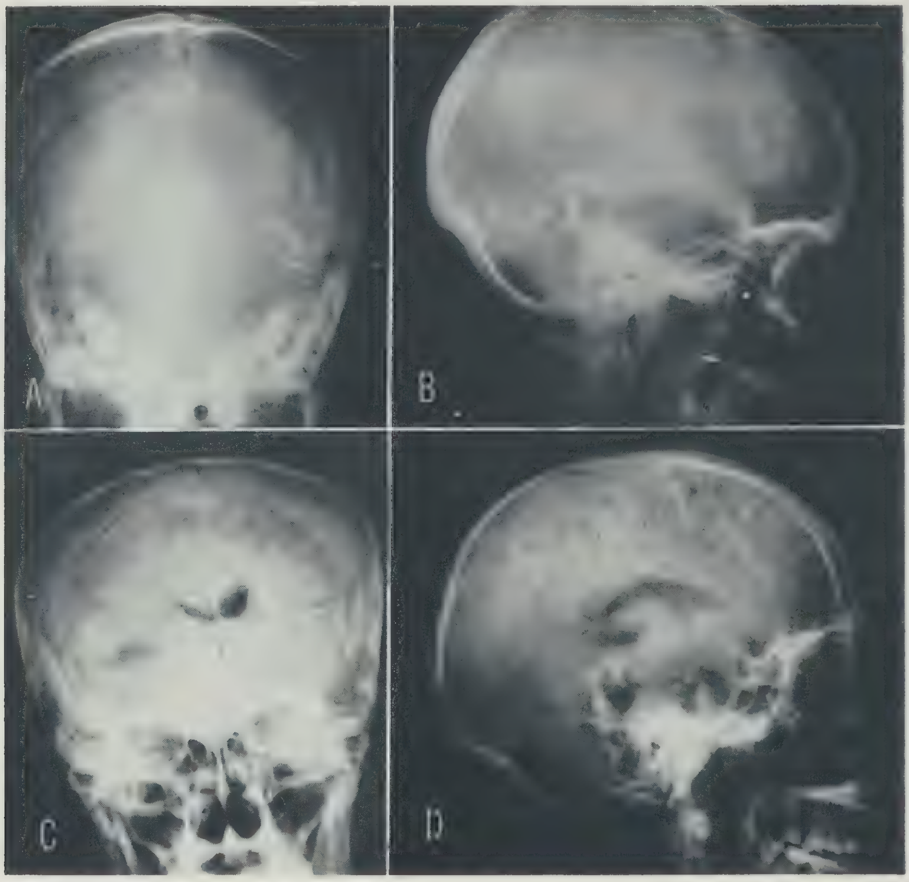

FIGURE 256 (case 5).—Encephalographic study of penetrating wound of head. A. Anteroposterior projection, showing penetrating wound in left occipital region outlined by fragments of bone carried deep into brain. B. Lateral projection. C. Pneumoencephalogram demonstrating porencephalic cyst at site of injury with shift of midline structures upward and to left and encroachment on ipsilateral ventricle. D. Lateral projection.

operation. This observation suggested that cerebral damage was diffuse rather than localized to the site of injury and made it important to determine whether changes in the brain extended beyond the injury area. Encephalography confirmed previous clinical impressions of the diffuse character of cranial trauma in gunshot wounds and proved ideally suited to the clarification of this problem.

3. To describe the radiologic manifestations of the cerebral abnormalities found. Only 1 of the 19 patients included in this study had an entirely normal encephalogram. In this instance, the bones of the calvaria in the anterior and middle fossae were fractured, and the major impact force of the

injury was expended upon the face. Although the damage was severe, encephalograms, obtained 5 days after injury, showed nothing remarkable.

In spite of presumably complete drainage of the cerebrospinal fluid before the examination in every case, the subarachnoid channels were not demonstrated in a number of cases. The explanation was twofold: Either the subarachnoid fluid was trapped and not amenable to drainage or the spaces were obliterated. In the 14 cases in which the spaces were obliterated, the effect of the changes was most notable near the wound of entry.

At operation, various explanations were found for the impaired visualization of the subarachnoid channels, including edema and maceration of the brain, subarachnoid hemorrhage, and arachnoiditis.

The subarachnoid markings were abnormally prominent in four cases, in three instances beneath the punctured calvarium and in the other at a distance from the wound. This observation, which in all instances was due to cortical atrophy, was not made in any patient examined less than 22 days after injury.

In three cases, in addition to subarachnoid abnormalities over the involved hemisphere, the cortical markings over the contralateral cerebral hemisphere were poorly visualized. In one instance, in which the air pathways under the bone defect seemed normal, the obliterative process was limited to the contralateral hemisphere (contrecoup).

The midline structures were found displaced in 6 of the 19 cases, the shift invariably being away from the injured hemisphere. One of the six patients had a small, penetrating injury, which produced minimal deviation from the midline. The other five had very severe injuries, with several large and many small shell fragments or depression of relatively large pieces of bone.

The ventricular abnormalities observed were extremely interesting. Ten patients, all but two of whom had suffered extensive head injuries, presented changes that involved large areas of bone and brain. In five cases, there was encroachment upon the lateral ventricle in the injured half of the brain. In seven, there was dilatation of the lateral ventricle within the injured hemisphere. Internal hydrocephalus, with dilatation of both lateral ventricles, was encountered once. In another case, the same findings were associated with diffuse cortical atrophy. This patient had been wounded 22 days earlier, and a .25-caliber bullet had lodged in the basilar portion of the occipital bone.

In this series, the earliest encephalographic evidence of ventricular dilatation was observed 7 days after injury. In another case, in which the examination was made 8 days after a severe penetrating wound of the left temporal lobe, a large porencephalic cyst was seen.

The basal cisternae were almost invariably well visualized. The cisterna chiasmatica was not visualized in 5 of the 19 cases, in 4 of which the injuries involved the frontal bone and frontal lobe.

That diffuse brain damage commonly occurred after penetrating gunshot wounds of the cranial cavity was amply demonstrated by this study. This situation was also well illustrated by the autopsy findings in another case, not

included in this series and not studied by encephalography. This patient died 52 days after sustaining a penetrating wound of the left temporal bone, with lodgment of the missile in the medial portion of the right occipital lobe. The left cerebral hemisphere, in addition to showing destruction of the left temporal, parietal, and occipital lobes, also showed marked diffuse atrophy, which was indicated by the size of the basal ganglia, the amount of white matter, and the extreme dilatation of the lateral ventricle, which was found bulging into the site of injury. The right cerebral hemisphere showed similar atrophic changes, but they were much less prominent.

EYE INJURIES

In jungle warfare, in which many injuries were caused by hand grenades, boobytraps, and small antipersonnel mines, multiple small penetrating wounds were often encountered. They were characterized by the presence of multiple foreign bodies, of various sizes, which looked like snow flurries of opaque debris. When the eye was involved in this kind of wound, it was sometimes impossible to distinguish intraocular and extraocular objects.

Sweet localization was not practiced in the theater, there being no apparatus for it, but a satisfactory technique was devised by Capt. (later Maj.) Harold G. Scheie, MC, and Colonel Hodes, which consisted of the injection of air into the retro-orbital tissues, followed by posteroanterior and lateral stereoscopic X-rays, without the Bucky diaphragm (*16*).

This technique, while it expedited the location of intraocular foreign bodies, had a serious disadvantage: It made immediate surgery hazardous, especially if the anterior chamber had to be opened. Then the injected air exerted pressure on the eyeball and predisposed to loss of vitreous and prolapse of the iris. Air was not absorbed for 3 or 4 days, and it was often undesirable to postpone operation for such a length of time. Carbon dioxide was next tested, but it was absorbed too rapidly to be effective as a contrast medium. Oxygen proved the ideal agent when surgery was necessary without delay. Most of it was absorbed within 4 to 8 hours, and only a small amount was evident 24 hours after the injection. Absorption was thus rapid enough to avoid the risk of loss of vitreous fluid at operation. Visualization was excellent. The technique was widely adopted and proved useful in the diagnosis of other retro-orbital abnormalities.

Semiopaque foreign bodies, usually bits of aluminum or impregnated paper, could be visualized by soft-tissue tangential views. This was a useful technique when the eye was involved and concern was felt about the possible development of contralateral infection (sympathetic ophthalmia) caused by the persistence of an irritant in the homolateral eye.

DIAGNOSTIC FLUOROSCOPY

Radiologists at a number of hospitals reported attempting to use fluoroscopy whenever possible because of the shortage of films. The substitution

was not satisfactory. Radiologists at the 73d Evacuation Hospital did not find the method useful in determining the status of fractures put up in casts (*5*). The casualties at this hospital were chiefly Chinese, and a large proportion had badly comminuted gunshot fractures of the extremities, many times with involvement of the joints. They arrived from the front in heavy casts applied after debridement, with very little accompanying information to guide the surgeons at the evacuation hospitals in the further management of their injuries. It was a waste of time and material to remove the casts if the fractures were in good apposition and alinement. It was essential to take action if they were not. Practically always, it was necessary to resort to radiography to obtain the desired information; fractures, especially when the joints were involved, were missed altogether or poorly evaluated on fluoroscopic examination through casts.

Fluoroscopy for head injuries was also promptly abandoned as a useless procedure. The gutter type of wounds of the calvarium, with fragments driven intracranially, required surgery, and it was important that such injuries be identified. They were well demonstrated on roentgenograms, but they could not be seen under the fluoroscope, no matter how careful the examination.

Diseases and Disease States

TROPICAL DISEASES

Much of the workload of departments of radiology in the China-Burma-India theater concerned tropical and other diseases and civilian-type trauma. Tropical diseases were rampant, and a number of new and interesting observations were made in them.

Malaria

All hospital units that went to the China-Burma-India theater had been alerted concerning the prevalence of malaria in the area and were prepared for the high incidence encountered. The experience of the 20th General Hospital is typical: It encountered a high incidence of malaria in both U.S. and Chinese personnel and patients, though considerably less in U.S. troops than had been feared.

From the radiologic point of view, an extensive investigation was conducted to establish the presence or absence of pulmonary lesions in patients with very severe malaria, especially of the tertian type. Repeated examinations showed no relation between the bronchopulmonary symptoms often present and the radiographic appearance of the lungs, which were almost invariably clear. The occasional focal areas of bronchopneumonic infiltration that were observed regressed as in the usual bronchopneumonia.

Hookworm

Authoritative reports indicated that 94 percent of the total population of the Assam area suffered from hookworm (*Ankylostoma*) infestation, and a high incidence was expected in U.S. troops. As a preparatory measure, shortly after the 20th General Hospital arrived in Assam, radiographic studies of the gastrointestinal tract were carried out on a number of healthy young men, so that presumably normal films would be at hand for comparison with films of those who might develop hookworm infestation. The opportunity for comparative studies promptly arose, and it was possible to study the victims of ankylostomiasis from the beginning of their illness—usually 6 to 25 days after exposure—until their discharge from the hospital after treatment (*17*). During the Battle of Myitkyina, a number of casualties were evacuated to the 20th General Hospital with unexplained fever, abdominal pain, leukocytosis, and eosinophilia, which were found to be caused by hookworm infestation.

A typical instance of the disease is illustrated in the following case history:

Case 6.—A 25-year-old soldier crawled under a mobile crane, with his back to the ground, which was infested with hookworm parasites. Within an hour, he noticed itching. A rash appeared the following day and lasted for 3 days. Four days later, he developed a cough, which lasted for 12 days (cough was so common in soldiers with hookworm that it came to be called "foxhole" cough). Vomiting appeared 16 days after exposure, and diarrhea 4 days later. When the patient was admitted to the hospital 31 days after exposure, the diagnosis was made at once from the history and was confirmed by laboratory tests and X-ray examination.

In this case, as in 60 percent of all cases in which roentgenograms were made, gastrointestinal abnormalities were observed (figs. 257–261). The esophagus and stomach and the duodenal bulb were normal, but jejunal tenderness was always present. The first X-ray abnormalities appeared in the proximal jejunum, about a month after the exposure, and then spread proximally, first into the distal duodenum and next through the ileum. The abnormalities took the form of excessive peristalsis, segmental contractions, and distortion of the mucosal pattern, all indicative of disordered motor function.

The mucosal changes were explained on the basis of an abnormality of the intramural nervous system and were considered to represent a disturbance in the reflex arcs rather than an actual thickening of the intestinal wall. It was difficult to conceive of changes in the mucosal appearance and the appearance of the lumen of the indurated intestine occurring with the speed that characterized the changes in the small intestine in this study. The radiographic observations seemed to bear out the views of Golden (*18*) who called attention to the importance of thickening of the small intestine as "a delicate balance between the sympathetic and the parasympathetic nervous systems, illustrated by 'disordered motor function.' "

What caused the damage to the intramural nervous system, if it was indeed damaged, was a moot point. It seemed highly likely that the hooklike teeth of the parasite were responsible. As they cut into the mucous membrane

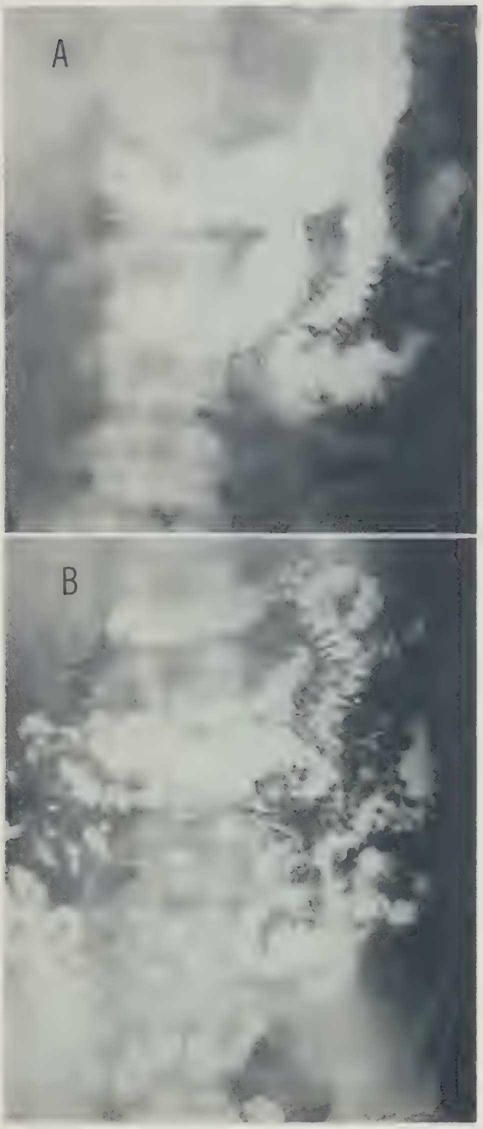

FIGURE 257.—Hookworm disease in patient with nausea, vomiting, and severe cramps for 6 weeks. White blood cell count 40,000 per cubic millimeter; 70 percent eosinophiles. A. Roentgenogram obtained 1 hour after ingestion of barium meal. There is considerable delayed motility and duodenal dilatation, and the mucosal pattern is distinctly abnormal. B. Roentgenogram obtained 2½ hours after ingestion of barium. There is diffuse irritability of the small intestine with long areas of peristaltic contraction and segmentation.

at the site of the imbedded buccal capsule, they may interfere with the elaborate network of nerve cells and fibers that extend to every part of the intestine from the subserosal, deep muscular, Auerbach's and Meissner's plexuses.

Bacillary Dysentery

Radiographic examination of patients with bacillary dysentery showed distinct abnormalities of the small bowel. The distal ileum, particularly, was

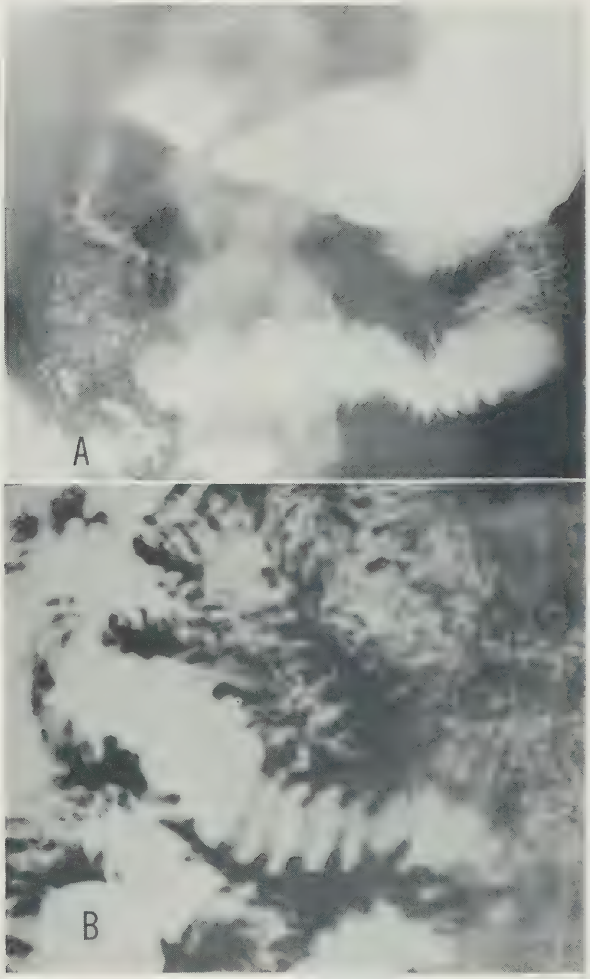

Figure 258.—Hookworm disease. A. Closeup of roentgenogram, showing proximal jejunum. The mucosal folds are wider and higher than normal and are irregularly spaced and point irregularly in all directions. B. Same, in another patient.

irritable, and the transit time of the barium meal in this part of the intestine was delayed. These findings might have been expected: As a rule, amebiasis affects only the cecum, but bacillary dysentery is no respecter of the small bowel (*19*).

Typhus

In 1944, a new febrile disease began to be observed at the 20th General Hospital, characterized by a rash; lymphadenopathy; conjunctival injection;

FIGURE 259.—Hookworm disease. Roentgenogram taken 30 minutes after ingestion of barium by patient who had complained of periumbilical pain, nausea, and weakness for 10 weeks.

neurologic, pulmonary, and renal manifestations; and sometimes cutaneous ulcers with satellite buboes. The disease was thought to be miteborne typhus, the Japanese form of tsutsugamushi fever. Its appearance was important, for with the opening of the campaign in northern portions of Burma, U.S. troops were inevitably exposed to it.

Colonel Hodes, in collaboration with Lt. Col. (later Col.) Thomas FitzHugh, Jr., MC, Chief of Medicine, 20th General Hospital, undertook an intensive study of scrub typhus. Their principal roentgenologic findings, which are recorded in the annual report of the hospital for 1944 (*4*), were as follows:

Changes in the chest were remarkable and apparently characteristic. Early in the illness, radiographs were essentially normal. Later, as dyspnea and cyanosis appeared clinically, the films revealed a slight cardiac enlargement associated with increased hilar and truncal markings. Still later, there was a considerable increase in the cardiac dimensions, and the appearance of the heart suggested lack of tone. At the same time, the hilar prominence increased, and the pulmonary findings suggested hypoventilation and were characteristic of the so-called drowned or wet lung (*20*). The dilatation of

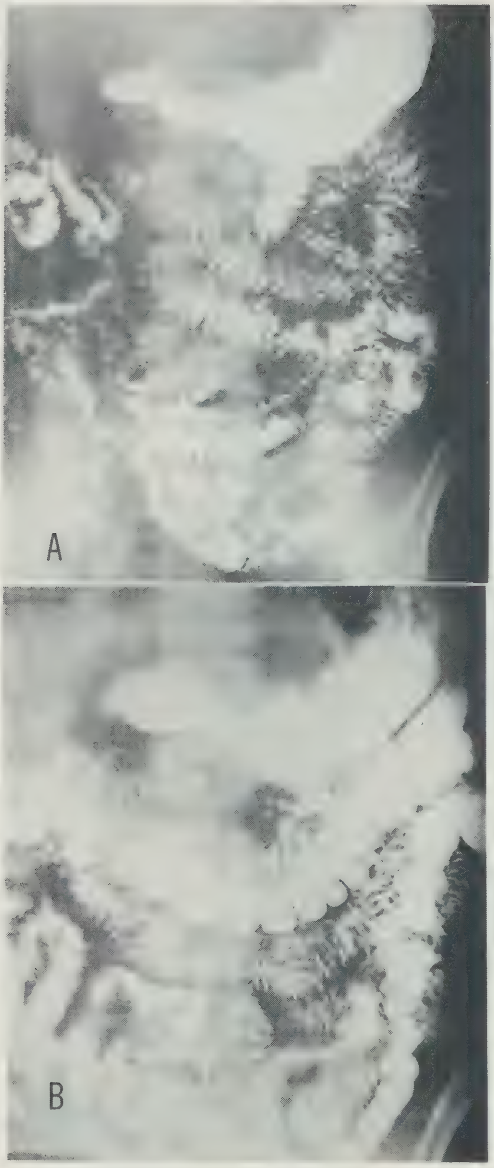

FIGURE 260.—Hookworm disease. This patient's chief complaints were nausea, postprandial cramps, and pain in the right upper quadrant for 10 weeks. A. Roentgenogram obtained 30 minutes after ingestion of barium. The barium stream is continuous but the bowel is hypertonic, narrowed, and shortened. The mucosal folds are coarse and are irregular in height, width, and spacing. B. Roentgenogram, 3 months later, also 30 minutes after ingestion of barium. The barium is already in the large bowel. The small intestine is less hypertonic than in the earlier roentgenogram but is still abnormal.

the heart almost invariably demonstrated by X-ray patients who were very ill with typhus was evidently a reflection of vascular collapse.

The lower lobes of the lung were more commonly involved than the upper. Definite densities were frequent and resembled those seen in bronchopneumonia. In patients with cardiac enlargement and bronchopulmonary infiltration and exudation, there was evidence of almost complete fixation of the dome of the diaphragm and absence of respiratory excursions.

Clinical improvement was followed by gradual regression of the abnormal

FIGURE 261.—Hookworm disease. Roentgenogram reveals marked disorder of the motor function throughout the duodenum, jejunum, and ileum, with hypertonicity. This patient complained of abdominal pain, nausea, and vomiting for 4 weeks.

chest findings until the lungs and cardiac silhouette eventually appeared normal. Slight pleural effusions occasionally developed, and slight residual pleural thickening was also occasionally observed after clinical recovery, but empyema was an extremely unusual complication.

Fluoroscopic examination, which of course was never undertaken in critically ill patients, showed no changes in cardiac pulsations or diaphragmatic excursions in patients who presented only slight cardiac and pulmonary embarrassment.

Eosinophilic Lung

Eosinophilic lung, a rather common condition in India, had been reported before the war in Englishmen who had spent a considerable time there, and it was feared that U.S. troops might contract the disease. Special studies were therefore undertaken to identify the condition without loss of time (*21*).

FIGURE 262.—Anteroposterior roentgenogram of eosinophilic lungs. Note that all lobes of both lungs are involved. This case is typical of those observed in the China-Burma-India theater.

The most striking feature of eosinophilic lung was massive eosinophilia. The total white count was characteristically 20,000 to 40,000 per cubic millimeter, and it sometimes reached 70,000 to 80,000.

The characteristic X-ray finding was pulmonary nodulation or mottling similar to that observed in miliary tuberculosis, silicosis, periarteritis nodosa, and metastatic malignancy. The diffuse pulmonary mottling present early in the disease was distributed throughout both lungs by the end of the second week of illness (fig. 262). The individual lesions were characterized by dense centers and ill-defined, blurred peripheries. The mottling seldom lasted more than 4 weeks, though the disease tended to persist in the absence of treatment by neoarsphenamine.

MALNUTRITION

The Japanese prisoners of war admitted to the 20th General Hospital after the Battle of Myitkyina in 1944 had been in hiding for 2 or 3 months, during which time they lived on a little rice and whatever they could forage from the land. All of them were suffering from severe malnutrition and from severe

vitamin depletion, particularly lack of vitamins A, B, C, and D. Hyperkeratoses and changes in visual acuity were the rule.

Colonel Hodes and Maj. (later Lt. Col.) Kendall A. Elsom, MC, became interested in these prisoners and undertook a comparative study of their status and that of U.S. combat troops who had served in the same area.

A radiologic study of 15 Japanese prisoners of war with severe nutritional imbalance showed no demonstrable abnormalities in the small intestine. In the comparable U.S. study, the tone and motility of the small intestine were definitely altered, and the pattern was abnormal. These changes appeared in patients with vitamin C deficiencies, and in those who were sensitive to Atabrine (quinacrine hydrochloride), but, amazingly, they did not appear in the Japanese, some of whom, because of their seriously malnourished state, were litter borne. Yet their upper intestinal tracts, including the stomach, duodenum, and small bowel, were entirely normal. No explanation for the differences was ever found.

It seems still more remarkable that later, when the Japanese patients were receiving an adequate diet and had begun to regain their muscle tone, radiographs of the small intestine began to reveal disordered motor function. It was thought that at this time edema resulting from ingestion of large quantities of fluid was being reflected in the small bowel. The reasoning was that, while the concentration of blood colloids was adequate when fluid depletion was total, edema resulted when fluids began to be ingested in large amounts. The disordered motor function persisted for several weeks before there was a return to normal.

Although no special radiologic studies were made, it might be mentioned that medical officers in the theater reported to the theater surgeon that the efficiency of the command was being reduced because the diet was deficient in calcium, thiamine, riboflavin, and vitamin C. A large proportion of the troops reporting for sick call complained of such symptoms of deficiency states as weakness, insomnia, lassitude, and gastric disturbances. An increase in the incidence of gingivitis was thought to have been caused by vitamin-C deficiency (*22*).

Investigation proved the importance of supplementing the diet of troops in the theater, especially those in the Ledo area, with B-rations and multivitamins. Implementing orders were given, but there were logistic difficulties, it being necessary to employ an airlift to transport much of the subsistence from Calcutta to Assam. There was, therefore, still some complaint of deficiency in the diet in September 1944. At the request of the theater surgeon, a more liberal hospital supplemental ration was provided, and a uniform ration system was adopted for all hospitals. The new Basic Subsistence Issue Chart was put into effect on 1 January 1945.

Radiologists themselves furnished specific occupational examples of vitamin depletion resulting from abnormal living conditions. After some time in the jungle, Captain Keefer noticed that he was missing fluoroscopic findings, and Colonel Hodes also observed a similar decrease in visual acuity. The only

explanation in both instances seemed to be a vitamin-A deficiency. The theory was confirmed when fluoroscopic ability returned to normal in each instance after quantities of vitamin A had been taken for several weeks, though not in the same dosages.

BACKACHE

A large number of the soldiers who complained of backache in the China-Burma-India theater presented syndromes suggestive of retropulsion of the intervertebral disk. Contrast media were available in the theater for urography (*23*), but Pantopaque (ethyl iodophenylundecylate) was not provided, and when a contrast agent was necessary for myelography, air was used. When the correct technique was employed, a remarkable proficiency in diagnosis was developed, as was proved by surgery later done on these patients (chiefly Chinese) in forward hospitals. So well were the abnormalities of the intervertebral disk demonstrated by air that some medical officers came to believe, as a result of this experience, that opaque solutions should be used only in unusual or obscure cases.

Section VII. Radiation Therapy

The Picker field unit carried with it instructions concerning its use for superficial X-ray therapy, but radiologists at the 20th and 142d General Hospitals, among others, found that its use at the recommended dosage settings did not produce satisfactory results, even when it was operated by qualified specialists. The 1943 annual report of the 20th General Hospital stated that the figures given were unquestionably safe averages of "r per minute afflux," but when they were utilized, they did not produce the radiotherapeutic results that past experience with accurately calibrated machines would lead one to expect (*4*).

Because no calibrating device was available in the theater, X-ray therapy was generally discouraged or refused altogether. R-meters were repeatedly requisitioned but were never received. If they had been available, a certain amount of superficial X-ray therapy could have been administered, though it would have been limited by the heavy diagnostic load, and patients who were being hospitalized or being evacuated to the Zone of Interior could have been treated and perhaps returned to duty promptly.

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Part VI

MINOR COMMANDS

CHAPTER XXXVI

Minor Commands

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Section I. The Alaskan Department[1]

GENERAL CONSIDERATIONS

The proximity of Alaska to both Russia and Japan was the probable defensive motivation behind the landing of troops on Elmendorf Field, near Anchorage, Alaska, on 26 June 1940 and the establishment of the military post designated as Fort Richardson (*2*). Except for the airfield, the site of the future post was then an undeveloped wilderness of low brush with some scattered high timber. Field installations were at once set up, and permanent construction was pushed as rapidly as possible by all hands, including the medical detachment that formed part of the original contingent.

Five outstanding factors influenced medical, and therefore radiologic, service in the Alaskan Department:

1. The extremely cold weather. The nights were cold during the summer, and the cold, which was often wet cold, was biting and piercing during the winter.

2. The high winds, often 100 miles an hour, were hard to endure even when snow and rain were lacking. They scattered the volcanic ash that was characteristic of barren spots in Alaska and that often covered floors with black, mineralized, siliconized dust half an inch deep. Its effect on X-ray installations can be imagined.

3. The heavy snows, often from 12 to 18 inches deep on the roofs of hospital and other installations. The accumulations had to be removed by an ingenious system of boards pulled back and forth by ropes tossed over the roofline.

4. The drenching rains that fell during all seasons. Flooding and subsequent undermining of installations were frequent. The buildings were not

[1] (1) Unless otherwise indicated, the material in this section of the chapter, aside from personal recollections, is derived from the official history of the Medical Department in Alaska in World War II (*1*) and the annual reports of the various station hospitals that served in this command. (2) Designation of the U.S. troops stationed in Alaska as Alaska Defense Command was announced by letter, AG 320.2, dated 4 February 1941. This command was assigned to the Western Defense Command on 12 December 1942. On 1 November 1943, Alaska became a separate theater of operations and the Alaska Defense Command was renamed the Alaskan Department.

insulated, and the effects of both water and ensuing dampness on X-ray equipment again can be imagined.

5. The almost total darkness that prevailed during the winter months and, in contrast, the almost total daylight that prevailed during the 4 summer months, though fog was frequent even during the summer. The darkness contributed to the high incidence of serious fractures of the hip sustained by soldiers who fell into trenches and emplacements while using inadequate slit flashlights (p. 792).

All the problems of medical practice that arose in Alaska proper were multiplied in the outlying islands, particularly the Aleutians, where the only combat in the command occurred.

ESTABLISHMENT OF HOSPITALS

The considerations just listed indicated the urgent necessity for replacing field (tented) installations with quonset huts and then with wooden hospitals as rapidly as possible. All phases of the weather demanded that medical care, including its roentgenologic phase, be carried out where heat and water were available and where water as such or in solutions would not freeze.

Construction of the 183d Station Hospital, which provided medical service for Fort Richardson, was one of the first medical projects undertaken in that area. It was a 250-bed hospital, of the cantonment type. Patients were received late in November 1940, and the hospital was completed the following April (fig. 263). Although it was termed a station hospital, it served in other capacities. In 1942, it began to receive patients from other small outposts and stations in Alaska, thus serving as a regional and general hospital. Also in 1942, it received casualties from hospitals on the Aleutians and evacuated them to general hospitals in the continental United States.

A second station hospital, the 500-bed 184th Station Hospital, was begun in 1942 and was located in the Dispersal Cantonment Area, 8 miles from the post. When it was opened in May 1943, the circumstances that had dictated its location had disappeared: Attu and Kiska had been retaken from the Japanese, the latter without a struggle, and there was no longer fear of harassing air raids. This hospital also provided services of a general hospital nature and was frequently, though inaccurately, referred to as a general hospital, the terminology perhaps reflecting the original intent of the command.

One of the most useful radiologic functions performed at the 183d and 184th Station Hospitals was the screening not only of combat casualties but also of patients with bleeding ulcers or other intestinal bleeding, and those with pulmonary tuberculosis or other diseases, before their evacuation to the Zone of Interior. The X-ray report was often used to help in the decision as to the mode of transportation; that is, by ship or air.

Aside from temporary tented field installations, which were evacuated as rapidly as possible, only station hospitals were employed in the Alaskan

FIGURE 263.—183d Station Hospital, Fort Richardson, Alaska. A. Hospital site, with wooded areas and mountains in background. B. Musical program in ward under direction of American Red Cross recreation worker. C. Main radiographic-fluoroscopic exposure room. D. Another radiographic-fluoroscopic exposure room, with facilities for dental radiography with field unit. E. Radiologist's office and consultation room, with film-reading conference in progress. The office occupies space formerly occupied by a waiting room. F. Another office and consultation room, communicating directly, in L-shaped fashion, with office shown in view E. G. Combined office, classroom, study for technicians, and administrative unit. Note bin for filing films.

FIGURE 264.—X-Ray Section, 179th Station Hospital, Adak Island, March 1943.

Department. In all, 30 were set up. The 23 that were activated as numbered station hospitals on 7 September 1942 (*3*) were widely dispersed. Those located farthest east were the 207th Station Hospital, which was on Annette Island, near Ketchikan, and the 212th, which was at Juneau. At that time, the farthest west hospitals were the 42d Station Hospital on Amchitka Island and the 179th (fig. 264), on Adak Island. The 328th (fig. 265) and 329th Station Hospitals, which were on Attu and Shemya Islands, respectively, were not activated until 26 September 1943.

These 30 hospitals, not always with the same personnel, served in the Alaskan Department for periods ranging from 5 months to almost 6½ years (map 9). They varied in size from the 25-bed hospital at Nome (fig. 266) to the 250-bed and 500-bed hospitals at Fort Richardson.

PERSONNEL AND TRAINING

Personnel

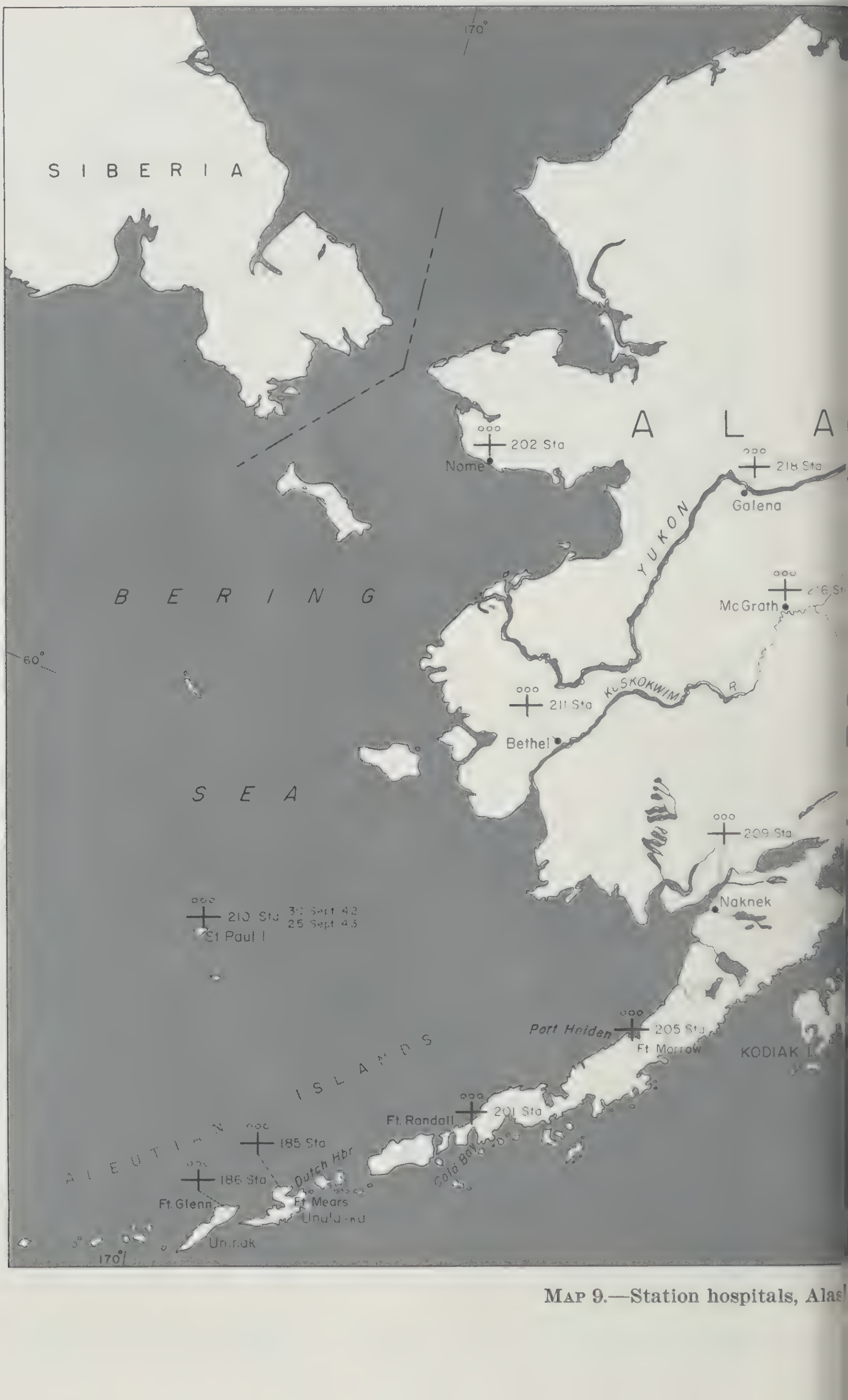
Although the tables of organization called for a radiologist for each station hospital, the medical records of the Alaskan Department show that only 19 medical officers served in this capacity for the 30 hospitals in Alaska and the adjacent islands. None of them were certified by the American Board of Radiology. The comparative isolation of the command, and the urgency and

FIGURE 265.—Facilities of 328th Station Hospital, Attu, Alaska, September 1944. Administration hut is in foreground, and third (frame) building houses the X-ray section and laboratory (camera faces northeast).

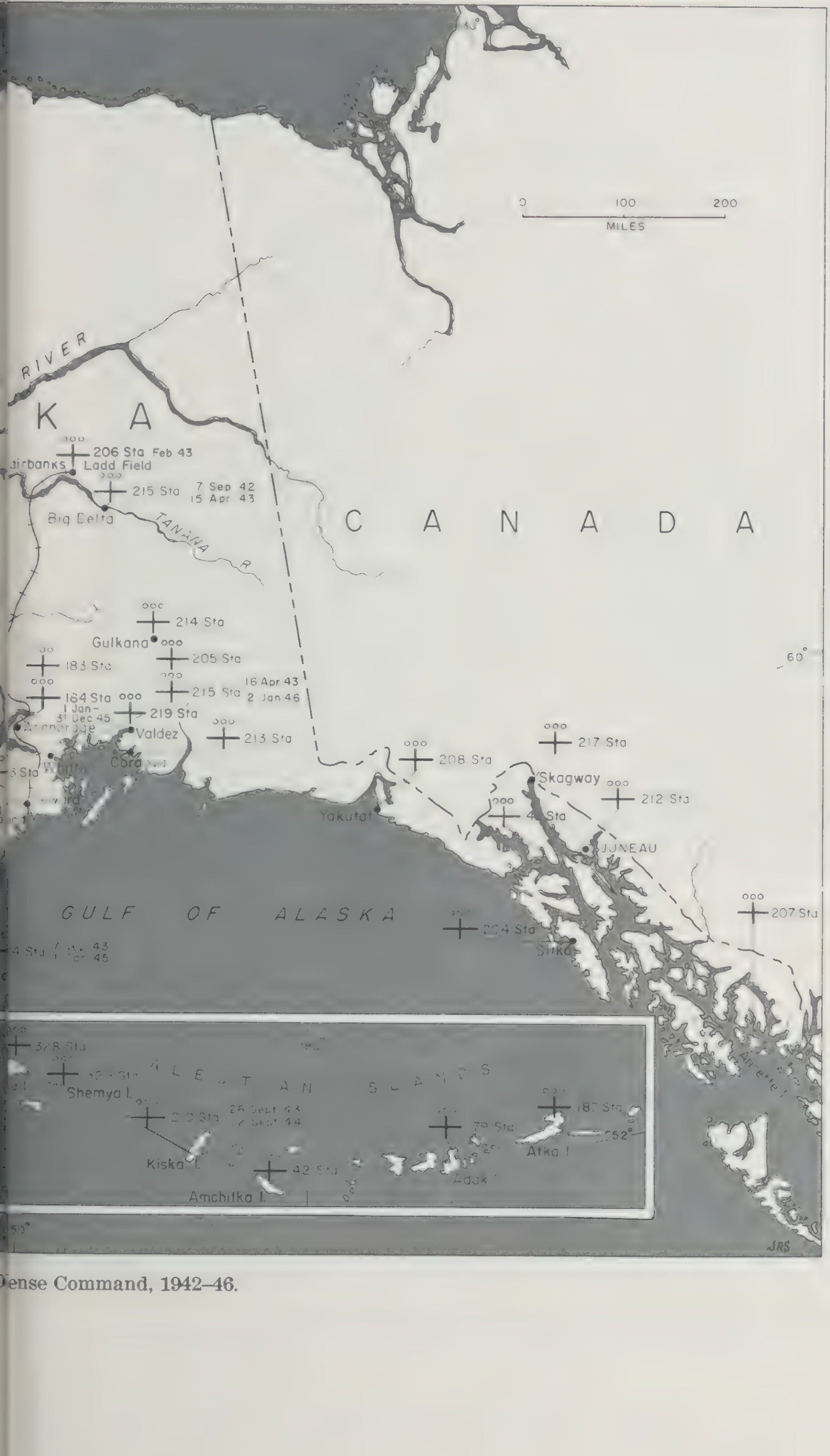
haste with which the medical units dispatched to it had been set up and activated, resulted in staffing problems which extended to the radiology service. Affiliated units, from which qualified radiologists could have been secured, were not sent to Alaska. Moreover, in the smaller, more outlying hospitals, the radiologic officer often read films as a matter of necessity and not because of any qualifications he possessed. In these hospitals, in fact, the radiologic officer was often, again of necessity, a general practitioner and sometimes the hospital surgeon as well.

A single radiologist, Capt. (later Maj.) Carl P. Olson, MC, was assigned to the 183d Station Hospital at Anchorage and served there for 28 months, meantime planning, and helping to supervise, the construction of the 184th Station Hospital nearby. He served, in effect, as consultant in radiology. Shortly after his appointment, Maj. (later Lt. Col.) Conrad E. Albrecht, MC, was named commanding officer of the hospital (p. 779) and proved most cooperative and sympathetic in all respects, including supplies, training, and all other radiologic matters.

X-ray technicians were generally in short supply, and few of them arrived already trained until 1943. Furthermore, their assignments were not always on the basis of their qualifications. One trained private, ordered to Kiska as an X-ray technician, was found digging latrines and burying Japanese clothing because of fear of cholera, dysentery, and other diseases. Fortunately, he was recognized by a medical officer as a graduate of the technicians' school at the 183d Station Hospital (p. 786) and was promptly



MAP 9.—Station hospitals, Alas



ʼense Command, 1942–46.

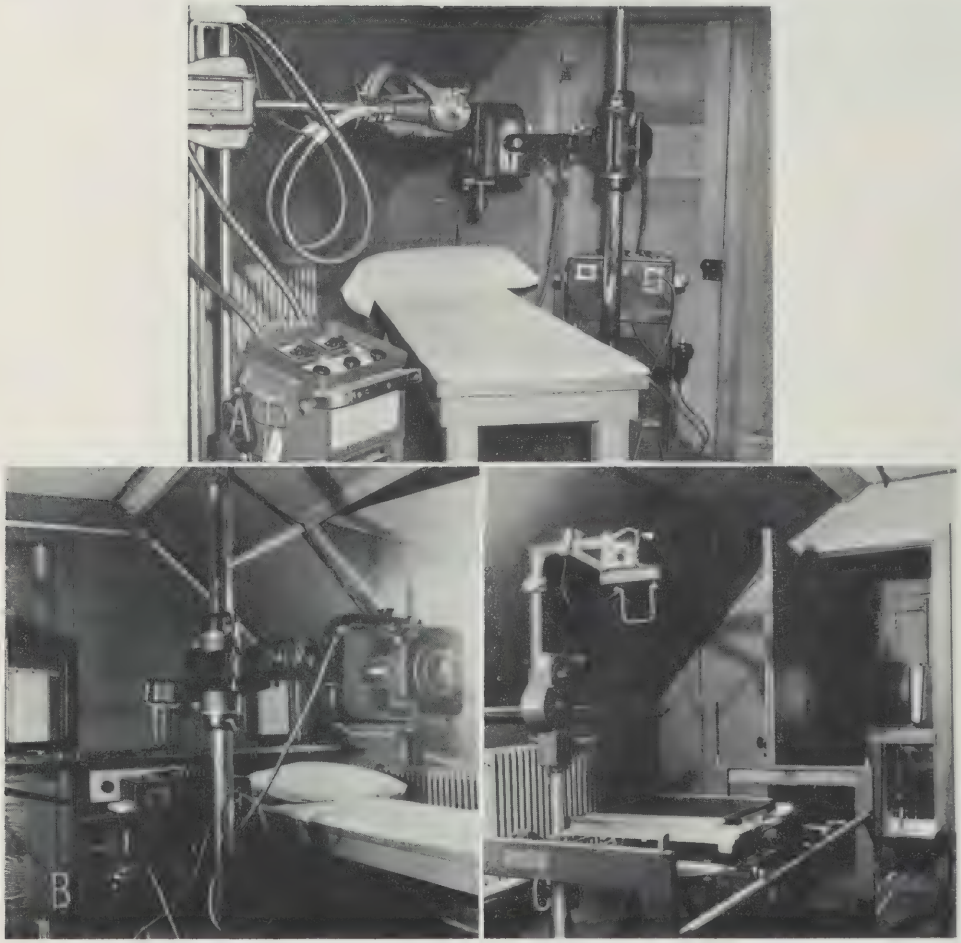


FIGURE 266.—Facilities of 202d Station Hospital, Nome, Alaska. A. X-Ray Department, showing Picker and Westinghouse units. B. X-Ray Room No. 1. C. X-Ray Room No. 2 and darkroom.

moved to a field hospital where he proved so useful (p. 786) that he was forthwith promoted to T/3.

The morale of the medical personnel, including radiologic personnel, in the Alaskan Department was remarkably high. The physical inconveniences of living, the hard and unfamiliar climatic conditions, and the restricted dietary could have produced disgruntled medical officers and enlisted men, but it did not, though the food supply, which was originally canned and stored foods, contributed to the development of a prescurvy situation, as indicated by the gingivitis, blepharitis, periodic diarrhea, and loose teeth experienced in 1942 and 1943. Food restrictions were inevitable during the first years of the command because all space on ships was allocated and air transportation

FIGURE 266.—Continued. D. General view of hospital site.

was not yet well established. The arrival of the first commercial ship with fresh food led one radiologist to pay $1.50 for a fresh cucumber and to eat even the skin with relish. When fresh vegetables and fruits were finally supplied, the prescurvy type of symptoms just listed disappeared in about 6 weeks.

In spite of the hardships mentioned, there was no evidence of poor morale in the reports of any hospitals in the command, nor was such an attitude reflected in any radiologic personnel who served in Alaska in the interviews and correspondence conducted with them in the preparation of this chapter.

Liaison

Liaison with the civilian population in the Alaskan Department adjacent to the 183d Station Hospital was close and amicable. One reason was the previous medical missionary work of Colonel Albrecht, executive officer and, later, commanding officer of the hospital. When he was commissioned, he simply continued the public relations he had practiced as a civilian physician. His good work was especially evident in the facility with which group surveys of tuberculosis were conducted in the command (p. 794).

Training

Officers.—The majority of medical officers who served in Alaska were from mixed sources, with key personnel supplied from the 183d and 184th Station Hospitals. An exception were the officers who served with the Arizona-trained troops who participated in the Attu campaign and some of whom were reassigned to the forces which landed at Kiska. Medical personnel of the latter forces consisted of medical officers indoctrinated in headquarters at Anchorage.

Captain Olson had been trained in the School of Roentgenology at Walter Reed General Hospital, Washington, D.C., under Col. Alfred A. de Lorimier, MC (p. 30).

The lack of formal training in radiology of officers assigned to the Alaskan Department as radiologic officers made local training imperative. Seminars and study sessions were set up at the 183d Station Hospital, and, with the cordial cooperation of Colonel Albrecht and of personnel of the sections of medicine and surgery, a great deal was accomplished.

Captain Olson, at the suggestion of Colonel Albrecht, reviewed the current medical literature available in the hospital library for presentation to the professional staff, as well as to enlisted personnel. In 1944, conferences lasting for several days were attended by all radiologic personnel in the command who could be spared.

Of particular value in the officer training program was the joint attendance on the weekly (later biweekly) conferences of the entire professional staff of the 183d and 184th Station Hospitals. These conferences were conducted in the fashion of clinicopathologic conferences in civilian hospitals. Also of great value were the special studies conducted on tuberculosis and other clinical problems (p. 794).

There was no formal training of radiology officers (or technicians) at other hospitals in the command, but the monthly conferences held at the 179th Station Hospital on Adak proved useful educationally to the medical officers without hospital connections who were assigned to nearby infantry battalions or first aid stations. At times, as many as 100 medical officers attended these conferences.

Technicians.—Few technicians, as already noted, arrived in the Alaskan Department already trained until after 1943, and requests for trained men were not honored. Some assigned to the last hospitals to arrive had been trained at the School of Roentgenology in the Zone of Interior (p. 40) and were intelligent, well qualified, and capable of handling routine work independently.

Some sort of training was essential for the untrained who arrived before this period, and a School for Roentgenographic Technicians was established at the 183d Station Hospital early in 1943. By the end of 1944, 20 students had been graduated from it.

The required course of study lasted for 3 months, and most of the stu-

dents elected to continue postgraduate study for another 6 months. Students were selected on the basis of (1) a previous interest in X-ray, including technical and mechanical interest or experience or sales experience, and (2) high school or college scientific training. The most fruitful training was accomplished in college graduates. An interesting observation was that several of the students registered in the school were educated personnel, disgruntled because of their assignments or in trouble with their superiors. They did highly creditable work both in the school and in later assignments.

The course of instruction was based on the curriculum of the School of Roentgenology at Walter Reed General Hospital (p. 40) and the School for Medical Department Technicians at Fitzsimmons General Hospital, Denver, Colo. (p. 123). Col. William W. McCaw, MC, the director of the latter school, incidentally, later served as area surgeon in the Alaskan Department, Anchorage.

Personnel of the school originally consisted of Captain Olson and two enlisted technicians, both well trained and one of them an expert in techniques of X-ray installation. Two of the graduates remained as instructors. One of them later rendered highly creditable service in the continental United States and, after the war, became a major executive in a commercial X-ray company. It might be added that in the Alaskan Department, as elsewhere, many medical officers and technicians without previous experience in radiology became so interested in their specialty that they remained in it after the war.

Army manuals on roentgenology (p. 357) were used as texts. Standard texts on radiology were also privately purchased in Chicago and were flown into the command through the courtesy of the Air Forces. Eastman Kodak Co., the Picker X-Ray Corp., General Electric X-Ray Corp., and Westinghouse X-Ray Co., on request, sent useful educational literature on current X-ray problems, including not only medical but also industrial radiology.

Instruction covered X-ray physics; fundamentals of electrical wiring and wiring diagrams; electromagnetism; atomic theory with discussions of electrons, protons, and neutrons; X-ray circuits; the manufacture of X-ray tubes and their theoretical basis; the complete use of both the Army field unit and the Army airflow unit, with emphasis on both field use in combat and institutional use. Students were also taught to identify, label, and file films and make use of clerical aids.

A great deal of attention was paid to the proper positioning of patients. This work, with other practical training, was conducted intensively and under careful supervision. Sterile techniques necessary for gallbladder and other special studies were also taught.

Requirements for graduation included passing oral and written examinations and the presentation of a thesis representing independent work. Time trials for mounting, disassembling, operating, and packing Army field units were held beforehand, and the best team was chosen for official inspection at graduation. The formal ceremonies were attended by the surgeon of

the command, the post surgeon, and the medical staff and nursing personnel of the hospital.

One very practical arrangement at the 202d Station Hospital, on Unimak Island and later at Nome (fig. 266), was the training of a pharmacist and a dental technician to substitute for the single trained X-ray technician when he was not on duty and to assist him in possible emergencies, when demands on the section would be increased.

Promotion

Graduates of the school for technicians at the 183d Station Hospital proved extremely efficient. They were proud of their technical work, and many medical officers agreed that their morale was greatly improved by their attendance at the school.

This attitude was fortunate, for the tables of organization were so set up that advances in rank were not possible for radiologic officers and promotions were similarly impossible for enlisted men. The situation was particularly disappointing to the technicians who had graduated from the school, which was one reason that so much emphasis was placed on formal graduation ceremonies. There was also emphasis on such morale-building considerations as personal cleanliness, proper uniform, and general appearance. The students were allowed extra privileges such as keeping their lights on beyond the specified time, so that they could read and study together. The privileges, of course, scarcely seemed to deserve that characterization when they were closely examined: Because of the burden of regular work, school instruction had to be carried on as an afterhours' activity, from 6 until 11 p.m., Sundays included.

Most attempts to provide ratings for enlisted personnel commensurate with their training and responsibilities were not successful. It took a great deal of maneuvering to secure specialist replacement for two technicians who had developed neutropenia and leukopenia (p. 790). When the radiologist put in his request, he was informed that in the Army privates were privates and specialists specialists, and substituting one category for another was not permissible, except in a combat area, which the Alaskan Department was not then considered. The specialist replacement eventually secured was valid only in the Alaskan Department. In spite of the proficiency of these two technicians, they would lose their promotion if and when they were assigned elsewhere.

FACILITIES

Temporary hospital facilities, as already indicated, were not practical in Alaska, particularly in the island chain. The combined effects of wind, snow, and rain played havoc with tented installations. When the 329th Station Hospital, for instance, landed on Shemya Island early in 1944, some men were quartered in pyramidal tents with wooden floors at the beach aid station,

but vicious winds and slashing snowstorms promptly "hammered and clawed" the tents to shreds and made it necessary to move the men immediately to unused hospital buildings.

X-ray facilities varied with the location of the hospital. The 183d Station Hospital (fig. 263) was a wooden structure, and its facilities consisted of a small X-ray room, a smaller darkroom, and a combined office and consulting room. The only viewing equipment was a stereoscopic machine in the middle of the corridor leading to the surgical wing and the pharmacy and adjacent to a door that let in 40°-below-zero weather when it was opened.

The planned approach to expansion was quite simple: The small office was filled with officers examining the films of their cases. Stale cigarettes, personally purchased as such by the radiologist, were handed out. The door of the office was closed, but the front door was opened for ventilation after the room was filled with cigarette smoke. Almost at once came the instructions: "You will have to do something about this." The result was a full-length shed attached to the original building for use as a second X-ray room. The errors incorporated in the X-ray department when the 183d Station Hospital was built were avoided when the 184th Station Hospital was built.

When the first air raid warning was issued after Captain Olson became radiologic officer at the 183d Station Hospital, he was also Officer of the Day. He at once commandeered all the heavy, wide tar paper in Anchorage, and, by the time other services tried to obtain priorities, he had all the windows in the hospital protected for blackout against air raids.

Quonset huts, such as the one occupied by the 179th Station Hospital (fig. 264), were frequently used and could be expanded as necessary.

The personnel of the 329th Station Hospital, with occasional help from a detail of infantrymen or a few artillerymen, erected their own hospital facilities on Shemya. The main body of the detachment arrived on 12 June 1943, after a 7-day trip from Adak. Their original equipment consisted of three shovels, four or five hammers, a couple of saws, and a keg of nails. By various means, not always orthodox, the equipment was increased to include 100 shovels, a number of picks, and other tools. Ground was broken on 17 June for the first permanent building, and within a week the beach (tented) hospital, which was exposed to the fury of the elements, could be closed. The work was carried out energetically, for many of the men had experienced one winter in the Aleutians. By mid-December, most of the 40 Pacific huts had been erected, at one time at the rate of 2 per day.

The X-ray section of this hospital moved from the beach area a week after its arrival and occupied a tent in the hospital area for the next 6 weeks. It then moved to its permanent quarters, two Pacific huts, which were later connected by a passageway that gave access, through another office, to the hospital library. During 1944, 2-inch wooden flooring was laid to reduce sympathetic vibration, and a better utilization of space was accomplished; like most other departments of the hospital, the X-ray department complained

of inadequate space. At no time, however, did the hospital reach its allotted capacity of patients.

In many hospitals, it was the custom to house the X-ray department and the operating rooms in the same building. The X-ray personnel of the 183d Station Hospital, contrary to the experience of most hospitals in this command and in other theaters, considered this an unwise plan because of patient traffic, the risk of surgical contamination, and the crowding experienced by both services when either had to be expanded. "A busy surgery and an active X-ray section," said the annual report of the hospital for 1944, "do not integrate well into the same housing facility."

EQUIPMENT

Basic Equipment

X-ray machines.—The larger station hospitals in the Alaskan Department were equipped with 200-ma. (milliampere) stationary X-ray units (items 60905 and 60915). The 183d Station Hospital at Fort Richardson was equipped with Philips Metalix (Dutch) units, which were installed before the United States entered the war. The hospitals at Fort Glenn and Fort Randall were provided with similar equipment in 1942, and the 184th Station Hospital later received the same kind.

This was an unfortunate selection. The experience reported by Maj. (later Lt. Col.) Isidor Ochs, MC (fig. 267), at the 179th Station Hospital, was typical of reports from other hospitals concerning this unit. It was assembled with the most careful attention to all details, but with the greatest difficulty, for many of the directions were in German. There were no German prisoners in the area. Navy technicians and engineers, Army engineers, Army Air Force electricians, radar officers, and every available physicist were called in to help. Some 20 persons worked on the machine continuously but unsuccessfully for 72 hours. The machine was taken completely apart and reassembled, still without success. Finally, one of the Picker mobile units was placed beside the stationary machine with the tube head mounted on the Bucky table.

At Fairbanks and at Fort Glenn and Fort Randall, the use of the Philips Metalix unit was meager, and films received for review by Captain Olson were of poor technical quality. At Dutch Harbor, the Philips unit was not operated at all until Sgt. James G. Hines, a graduate of the Anchorage technicians' school, was able to put it into working order.

This equipment repeatedly required new tubes and rewiring, which complicated the already difficult repair situation (p. 786). The use of foreign equipment in the U.S. Army was not wise and should not be repeated. Difficulties with its use in World War II would of course have been fewer if an

FIGURE 267.—Maj. Isidor Ochs, MC, Radiologist, 179th Station Hospital, Adak Island, April 1943. Note that the use of a single leaded apron affords incomplete protection of the lower extremities.

efficient repair service had been in operation when the United States entered the war.

In September 1942, the Surgeon, Alaskan Department, decided that extensive and specialized X-ray procedures should be discouraged in hospitals with only portable facilities and that patients who needed such studies should be transferred to the 184th Station Hospital, where adequate equipment and trained personnel were available. Hospitals which had only the Picker Army field unit (item 96085) should limit their work to "field type operations;" that is, chest surveys, fractures, and other emergency work. The field machine was not intended to serve as a power source for special investigations of the gastrointestinal tract, the urinary tract, the skull, or the endless complaints of pain in the back. This regulation was designed to protect both operator and patient from excessive exposure to radiation.

The field unit, when used for the purposes for which it was intended, gave the same excellent service in the Alaskan Department that it gave in other parts of the world. It was easily transportable, easy to repair, and easy to operate. The 179th Station Hospital on Adak had three portable Picker units, which its trained technicians could put into operation within 5 minutes.

One unit was kept in surgery for cystoscopic work, and another was used for portable roentgenograms on the wards.

It was reported from many areas in the Alaskan Department including the Aleutian Islands, that the Picker unit had been subjected to subzero temperatures without adverse effects. The cold climate, in fact, had little effect on any radiologic equipment and supplies except fixing powders, which were sometimes spoiled by moisture.

Loading.—There had been careful planning for the loading of X-ray equipment for the Kiska invasion, and two units of each type of portable machine were to be stocked on separate ships. The plan did not work out, and the equipment was hopelessly jumbled on the beach when the graduate of the technicians' school already mentioned, who was occupied burying Japanese clothing (p. 775), was assigned to the task of sorting the equipment out and setting it up. Sgt. Thomas Johnson, then still private, first class, did a highly creditable job and set up an efficient diagnostic unit, with which he took an emergency roentgenogram of the fractured hip of a colonel.

Tubes.—Tubes were frequently received broken, because of poor packing and rough handling during shipment. A particularly inefficient method was the packing of tubes in orange crates, with web suspension. Although the manufacturers were repeatedly informed of the breakages, they were still occurring, and for the same reason, as late as 1944.[2] In January 1942, the command surgeon authorized all hospitals to stock one replacement tube for each machine on hand. Later, it was recommended that the supply depot be allowed to keep in reserve anode and cathode tubes, which are not interchangeable. Such a policy was necessary because of the several months required to replace broken tubes by requisition. It took 3 months to replace a tube that arrived broken at the 329th Station Hospital, and a tube that burned out early in November 1942 had still not been replaced at the end of the year.

Current.—Fluctuations in voltage and abnormally low current made for persistent difficulties at many stations. Only a brief experience was necessary to show that it was unwise to rely upon local sources of power, at least during the early operation of new stations, and it was recommended that a generator (item 96060) be part of all shipments of departmental X-ray equipment.

Repairs.—Repairs of X-ray equipment could not be accomplished at individual station hospitals by hospital personnel, and, by the end of 1942, there was urgent need for the assignment of an X-ray serviceman who could visit the hospitals and perform the necessary repairs. Although a request was made for the assignment of two officers or enlisted personnel for this work early in February 1942, no action was taken on the request until July 1943. Then, during July, August, and September, an officer of the Sanitary Corps, assigned to the Seattle Army Service Forces Depot, was placed on temporary

[2] As late as 1960, tubes were being received by civilian radiologists packed in this same inefficient manner. In 1963, they were being packed securely in Styrofoam and were being received in good condition.—K. D. A. A.

duty in Alaska for this purpose. He visited the major mainland stations, provided the necessary repair and maintenance service, and made recommendations for the improvement of X-ray facilities.

Repair of X-ray equipment formed part of the instruction at the technicians' school at the 183d Station Hospital, and Sgt. James G. Hines, after having completed the prescribed course there, was assigned to service the equipment in the command.

Sergeant Hines carried out his assignment most satisfactorily. He found that most of the difficulties encountered with the equipment in the command were caused by improper packing and inadequate care by inexperienced personnel. The troubles, linguistic and otherwise, with the Philips Metalix unit have already been mentioned (p. 784). When the Picker field unit was correctly operated, it seldom gave any trouble.

Sergeant Hines found that at times merely getting to the hospitals to do the work was a major undertaking in itself. Air travel was the most efficient means of getting about, but he was frequently bumped because of the weight of his tools or for other reasons. On one occasion, en route to Dutch Harbor, the ice spray froze to the superstructure of the boat, which would have capsized unless everybody on board had assisted in hacking and chopping the ice away.

Darkroom tanks.—Most X-ray departments complained that they needed more processing tanks, but most of them also complained of lack of space and agreed that they would have no room to place additional tanks in the darkroom if they had been available.

The chief problem with processing equipment was not related to shortages but to lack of running water. The 329th Station Hospital, for instance, had none for 8 months, and some hospitals never had any. In such circumstances, water had to be dipped from a nearby lake or stream, usually after the ice had been broken. Water from these sources was almost always dirty, and, while grass and debris could be filtered out of it, sediment could not be, and the dry films were often coated with it. Also, without running water, the wash water could not be changed as often as was desirable, and most films were not thoroughly washed. If water was available in pipes well below the surface, they had to be pumped out constantly to prevent freezing.

When X-ray sections were housed in tents, it was often impossible to keep the temperature in the developing solution at even approximately correct levels. In fact, the solution was often found frozen in the morning. One ingenious technician slipped a laundry bag over his tank at night and kept a kerosene lamp burning under the bag. The solution did not freeze, but his idea did not solve the problem of daytime fluctuations of temperature in the solution. These difficulties did not develop in hospitals with adequate heating arrangements. In these hospitals it was also possible to store water for future use without fear of its freezing. The use of baffles to keep the wash

water in motion in the processing tank was helpful when water supplies were low in freezing weather.

Accessory Equipment

Cassettes were often in short supply, and screens were often outdated as well as mismatched (with 2A or 2B screens, instead of A and B screens). Each cassette should have been prepared selectively, with a front screen and a back screen, since fluorescent quality of screens is different, and properly molded and paired front and back screens have a balanced intensification necessary for satisfactory films.

Film trimmers and shears were not provided, but these deficiencies could be overcome by trading with members of other services.

Repeated requisitions for extra view boxes were ignored, and, at the 183d Station Hospital, in spite of this hospital's heavy workload, most interpretations were made on stereoscopic view boxes with the single illuminator provided in the radiographic room. The 184th Station Hospital, 8 miles away, was well supplied with illuminators, but attempts to transfer some of them to the 183d Station Hospital, where training of officers and technicians was an important radiologic function, were never successful.

Inadequacies of equipment included the toilet facilities essential for barium enema examinations. At the 179th Station Hospital, the X-ray hut was built against a wall of earth, for protection against bombing raids, and a crude ladder was erected from it to the top of the earthen embankment and to the slit trench, about 30 yards away, which substituted for toilet facilities. The arrangements worked a considerable hardship on patients but on occasion furnished considerable amusement to technicians watching them from below as they tried to reach the summit.

Improvisations

Some improvisations were no more than adaptations of old methods. Folded towels, for instance, were used as compression bands, or the radiologist without stereoscopic equipment learned to cross his eyes when reading stereoscopic films. All students at the technicians' school were taught this trick. Other short cuts and improvisations were as follows:

1. The fluoroscopic unit (item 96215) was not satisfactory for routine radiography, and, at the 329th Station Hospital, the table was combined with the field unit (item 96085). The combination, though cumbersome to manipulate, gave satisfactory service. The attempt at reconversion was admirable in the absence of standard equipment, but it made protection against radiation damage more difficult.

2. At the same hospital, with the help of Ordnance personnel, vertical fluoroscopy was carried out with a stand designed and constructed for use with

the controls and shockproof head of the fluoroscopic unit (item 96215). The usefulness of the original equipment was thus greatly widened.

3. Many hospitals, before permanent facilities were available, used wooden frames covered with blankets for their darkrooms.

4. Wooden yokes were constructed at the 183d Station Hospital to cradle X-ray tubes above improvised tables.

5. At this hospital, and also at the 184th Station Hospital, polygraphs for gastrointestinal studies were constructed by the hospital utilities section.

6. Various expedients were used to dry films. A drier was constructed consisting of a wooden frame suspended above an oil heater. An exhaust fan to the interior of the processing room warmed the frigid air and shortened the drying time. A drip rack placed over the wash tank reduced the time within which wet films could be read.

7. Sinus boards and headrests were made from Bakelite obtained from the Signal Corps.

8. A telescopic cone improvised by civilian engineers and adaptable to field units made for greater local clarity and better definition in spot views.

Films

Films were generally in adequate supply in the Alaskan Department, though, in November 1943, headquarters advised that orders would be reduced and shipments delayed. At this time, a year's supply of films was on hand, according to the annual report of the 329th Station Hospital, but, if they were used with the stringency advised, all of them would reach and exceed their expiration dates. Many of them, moreover, had already deteriorated, as the result of exposure to heat on shipboard and to moisture because of unavoidably poor storage facilities. Some of them also had static marks on them, which hindered interpretation.

Whenever a temporary shortage of films was in effect, it was the practice of many hospitals to evaluate all requests for examination and refuse those not considered justified. Fluoroscopic examination was sometimes substituted for the radiographs requested.

Disposition of radiographs.—At the 183d Station Hospital, the radiologic officer insisted that, when groups of patients were evacuated to the Zone of Interior, their radiographs, properly identified by requests and requisition numbers, must be packaged and sent with them. This arrangement was entirely satisfactory. Permitting the individual patient to carry his own films was not. Whenever it was tried, numbers of films failed to appear at the Zone of Interior hospitals to which the patients were assigned.

The Alaskan experience indicates the advisability of protective tropical packing of films, even in cold climates. The cold itself does no damage, but moisture, dampness, and heat during storage can do a good deal.

Records

In connection with the discussion of films, it should be mentioned that a serious bottleneck in departmental records could have been averted if an adequate number of standard record forms (WD MD Form 55K–2, Radiologic Report) had been provided. If they had been, triplicate records could have been made, one copy to be retained in the X-ray section, one copy to be sent to the ward, and one copy to be attached to the films that accompanied the patient when he was transferred. In some hospitals, the shortage was made up by the use of mimeographed forms. In others, in which radiologic work was done by officers without training and simply of necessity, little attention was paid to the maintenance of either records or radiographs once the films had been read.

PROTECTION

Protection of personnel in X-ray departments was a matter of great importance and of considerable difficulty. In permanent installations and in the quonset hut type of installations (p. 783), lead lined fluoroscopic rooms were usually provided and operators could retire to protected control rooms during the period of exposure. When such protection was not available, the chief reliance was on the factor of distance. Wearing of rubber gloves and aprons was regulation. Leaded rubber aprons, however, did not extend far enough down the operator's body to protect his legs completely (fig. 267), and a second apron was frequently used below the first.

The ineffectiveness of protective measures was well demonstrated at one station hospital in 1944, when two technicians had to be relieved from duty because of progressive leukopenia, neutropenia, lassitude, and weakness. This situation developed in spite of the insistence of the radiologist, Lt. (later Capt.) Paul C. Dietz, MC,[3] that the operator (1) maintain maximum distance from the X-ray tube (as far as was possible without a remote control room), (2) wear a protective apron and gloves (0.5 mm. equivalent lead thickness when they were new) for all exposures greater than 3 seconds, and (3) employ a sheet metal screen for exposures of lesser duration. These instructions had not been uniformly obeyed by the affected personnel.

Lieutenant Dietz repeatedly demonstrated (on one occasion to an assembled medical staff) that milliamperage and kilovoltage of a degree commonly employed during fluoroscopy was sufficient, under the arrangements then in force, to illuminate a radiographic screen at a distance of 20 feet through the full thickness of the walls of both Pacific huts and the intervening 4 feet of space and to reveal clearly the skeletal structures of an interposed hand. This phenomenon occurred whether the tube was directed

[3] Lieutenant Dietz was one of the numerous medical officers assigned to radiologic duties without previous experience in the field. He was most proficient, and, as this experience proved, most conscientious. He well deserved the commendation he received in the annual report of the 329th Station Hospital for 1943.

toward the screen or away from it. Scattered radiation of similar intensity was demonstrated within a radius of 25 feet throughout the area, regardless of intervening walls and structures. The tube housings and the protective apron in use proved permeable to radiation. When, however, oil drums filled with water were stacked between the two huts, there was an approximately 50-percent reduction into the adjacent room.

This demonstration clearly showed that, in addition to the risk to radiologic personnel, no portion of the X-ray department, of the hospital library, or of the offices of the chiefs of services was protected against direct and scattered radiation in cumulatively harmful proportions.

All possible precautions were at once taken to eliminate this risk. The working hours of technicians were reduced. Scattering of rays was reduced by the use of a grid provided on the screen of the fluoroscopic unit. An improved cone was used. A vertical screen, 36 by 72 inches, covered with sheet metal, was improvised for the protection of operators. Rules about gloves and aprons were strictly enforced for all exposures. Complete blood counts were made monthly on all radiologic personnel. Finally, requests for all radiographs were scrutinized, and only those considered really urgent were filled until the lead sheeting ordered by the Corps of Engineers for complete screening of the department was received.

At some hospitals, rules for protection of personnel continued to be broken. When a broken fluoroscopic glass was replaced by ordinary window glass instead of leaded glass, the radiologist who permitted the substitution developed such a severe radiodermatitis that he had to be evacuated to the United States.

A similar instance was observed by Captain Olson. A recently commissioned radiologist, assigned to the 183d Station Hospital, reported to duty with obvious X-ray burns of the face. Knowing the conditions in Alaska, and especially in the chain of islands, Captain Olson recommended that he be returned to the United States and denied further X-ray service in the Army. His history indicated that, while he was in private practice, he had replaced the broken leaded glass in his fluoroscopic unit with unleaded plate glass, which offered no protection from the X-rays. Their cumulative absorption in the skin produced severe telangiectatic areas, especially on the forehead, nose, and malar prominences, and the severe radiodermatitis had culminated in basal cell carcinomas in the various affected areas. It should be emphasized again that these injuries occurred in private practice, not in military service. The condition was probably considered acne on the officer's preservice examination.

Two precautions against X-ray damage were recommended in the Alaskan Department:

1. Hand fluoroscopes should cease to be Army issue.

2. All fluoroscopic units should be supplied, when they were delivered, with additional leaded protective glass, so that, if the original glass were broken, it could be replaced at once with the same kind of glass.

CLINICAL CONSIDERATIONS

Aside from the casualties from the Attu campaign, there were relatively few wounded combat casualties cared for in the Alaskan Department. Most of the other casualties were suffering from cold injury, which was sustained on both Attu and Kiska. Some were suffering from gangrene of the foot, toes, and ankles, and, in a few instances, of both lower legs. The particular radiologic interest in these cases was a determination of the bone damage which occurred in the severer types (*4*).

The combat casualties from the Attu campaign were received at the 183d Station Hospital by air transportation, which was frequently interrupted by fog, snow, wind, and cold. Casualties from the Kiska campaign occurred within the occupying forces, during the initial patrols, before it was evident that the Japanese had already evacuated the island. These casualties were usually transferred to the 184th Station Hospital. The casualties from both Attu and Kiska were often examined in the X-ray section while infusions and transfusions were running. When they became transportable, or if they needed no immediate surgery, they were evacuated to Zone of Interior hospitals on the west coast.

Many combat casualties had sustained fractures, and the incidence of noncombat fractures was unusually high in all hospitals. Attention has already been called to the large number of fractures of the hip sustained when soldiers who had lost their way and were using slit lamp flashlights fell into trenches and emplacements during blackouts (p. 772). Many of these injuries were so severe that evacuation to the Zone of Interior was necessary. Fractures of the carpal navicular bone were frequent; many were sustained under the circumstances just described. A number of march fractures were also observed.

Aside from these special injuries, radiologic practice in the Alaskan Department was much like civilian practice. Patients with such conditions as pulmonary tuberculosis, bleeding ulcers, colitis, suspected malignancy of the lower bowel, and other serious diseases were transferred at once to the 183d and 184th Station Hospitals for further diagnosis, as were all obscure cases seen in the smaller hospitals. Electrocardiograms were processed in the X-ray section. Intravenous pyelograms were usually carried out in the X-ray section and retrograde pyelograms on the surgical service. Fluoroscopy was only occasionally used to set fractures, and then with extreme precautions; the practice was not encouraged. Fluoroscopy was not used for the removal of foreign bodies. Sweet localization was used for the removal of foreign bodies in the eye; there were numerous such cases.

Caseload

The caseload in the hospitals in the Alaskan Department averaged from 3,500 to 8,000 examinations per year per installation. In 1944, for instance,

the 329th Station Hospital made 3,630 roentgenograms, the figure including the dental examinations made from January through May. At this time (May), the dental section acquired its own X-ray equipment. The X-ray section also carried out 190 special studies, such as gastrointestinal and K.U.B. (kidney, ureter, and bladder) examinations, cholecystograms, barium enemas, pyelograms, stereoscopic studies of the chest and skull, and soft-tissue roentgenograms. The hospital equipment was designed for field use, but the exigencies of medical practice necessitated its use for practically the entire field of roentgenography. Such precautions as were possible were observed, and routine blood counts were made on all radiologic personnel.

In 1945, the 206th Station Hospital made 3,803 roentgenograms but conducted only 139 fluoroscopic examinations. In this hospital, as in other smaller hospitals equipped only with field units, the radiologist had to accomplish his tasks as best he could, with the assistance of his technicians. He did not have proper facilities for such studies as bronchography, sinus examinations, and gastrointestinal series, and patients who required them were, as previously stated, referred to the 183d and 184th Station Hospitals.

In 1944, the activities of the X-ray section of the 183d Station Hospital covered 8,588 examinations on 7,845 patients, the figures including the processing of 3,998 dental films and 190 electrocardiograms. The number of films used averaged 2.4 per case.

During 1945, the X-ray section at the 179th Station Hospital performed 6,797 examinations on 5,567 military personnel and 1,174 civilian personnel. The work was distributed as follows:

Area or type of examination:	*Number of examinations*
Skull (including mastoid and sinuses)	538
Extremities	2,189
Chest (fluoroscopy, bronchography)	135
Chest (excluding fluoroscopy and bronchography)	2,442
Ribs	32
Spine	679
Abdomen, flat plate	121
Esophagrams	41
Gastrointestinal series	329
Barium enemas	98
Gallbladder studies	101
Intravenous pyelograms	67
Retrograde pyelograms	15
Urethrograms	8
Foreign bodies (fluoroscopy and X-ray)	2
Total	6,797

SPECIAL STUDIES

A number of special studies made at the 183d Station Hospital were described in the annual report for 1944. Two concerned pulmonary tuberculosis:

1. The first of these studies was a survey of the 279th Infantry Regiment, most of whose men had been inducted into service before X-ray examination of the chest had become routine at induction centers (p. 101). In all, 21 cases of tuberculosis were identified, ranging from minor to unstable types to lesions of serious prognostic importance.

2. The second of these studies was a survey of natives (Eskimos, Indians, and Aleuts) and mixed strains of French, Russian, and German extraction who lived, for the most part, on or near Fort Richardson. The survey was undertaken to screen them for civilian employment or military induction. It covered approximately 800 persons, 30 of whom were found to have open tuberculosis; the ratio was about 8:1 as compared with the ratio of U.S. Army personnel serving in Alaska. Only a few months, and in some instances weeks, before, some of these men under the control of G–2 (intelligence) had carried out scouting operations on Attu, Kiska, and Shemya, and it is believed that the ruggedness of the weather and terrain had precipitated recurrences of latent tuberculosis.[4]

Apicography, which was developed at the 183d Station Hospital, was a refined delineation of the apices. Radiographs were taken in the routine anteroposterior and posteroanterior positions, and subsequent projections permitted a minute study of the apices to determine the existence, nature, and position of suspected lesions and adhesions. These studies were particularly important in the preparation of native-born Alaskans (Eskimos are a pure race) for neumothorax, a form of therapy used with considerable success on the medical services at the 183d and 184th Station Hospitals.

In cooperation with the internist, fluoroscopic and teleoroentgenographic studies (posteroanterior and bilateral oblique) were made of the chest with barium in the esophagus. This technique permitted the identification and recording of universal cardiac hypertrophy or other changes in the cardiac silhouette. It also demonstrated pathologic changes in the aortic outline and clarified cardiovascular and related pulmonary lesions. Finally, in the absence of nomographic cardiac charts, it was useful in mensuration of the heart.

Equipment for spot film studies of the gastrointestinal tract was lacking at the 183d Station Hospital, but a satisfactory substitute technique was developed. The initial fluoroscopic investigation was made, and the roentgenologist dictated the findings to a technician who used a system of shorthand devised for this purpose in the X-ray section. Then, using the so-

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[4] This survey, which was duly reported to Col. Esmond R. Long, MC, Consultant in Tuberculosis, Office of The Surgeon General, is believed to have been at least indirectly responsible for the millions of dollars later appropriated for the control and treatment of tuberculosis in Alaska.

called physiologic contrast load, X-ray projections were made with weighted amounts of barium at various time intervals. The technician carefully recorded all of these details. This technique greatly enhanced the accuracy of the diagnosis of such lesions as gastric and duodenal ulcers and frequently differentiated between nonorganic disease and organic disease that had been diagnosed elsewhere.

Intubation studies of the small bowel and double-contrast studies of the large bowl were also made.

No proprietary medium was available for contrast studies of the gallbladder, but tetraiodophenolphthalein mixed with grapejuice proved both palatable and efficient. Lipiodol was used for contrast studies of the paranasal sinuses and mastoids and for bronchography. Diodrast (iodopyracet) was used for intravenous urography and proved particularly useful in the delineation of tumors as well as other renal pathologic processes. A number of men with renal tumors had to be operated on at the 183d and 184th Station Hospitals because their hematuria was too severe to permit even air evacuation to the Zone of Interior. No myelographic studies were made.

Interesting observations were made on cleidocranial dysostoses, several of which were found in the examination of Eskimo natives. In one family, the absence of clavicles was associated with the presence of multiple dental roots.

RADIATION THERAPY

X-ray units provided to the station hospitals in Alaska had been calibrated for superficial therapy, but the command surgeon did not permit their use. Chronic skin conditions were sometimes aggravated by climatic conditions, and, in such cases, since radiotherapy was forbidden, the patients had to be evacuated to the Zone of Interior.

CARL PORTER OLSON, M.D.

Section II. The Caribbean Defense Command, Trinidad, Brazil, and Liberia

THE CARIBBEAN DEFENSE COMMAND

The Caribbean Defense Command was established in the spring of 1941 to coordinate the military activities of the Panama and Puerto Rican Departments with those of the Caribbean bases acquired from Great Britain in the destroyers-for-bases agreement of September 1940. Three sectors were set up:

1. Panama.

2. The Puerto Rican Sector, which included the Virgin Islands, Cuba, Jamaica, and Antigua.

3. The Trinidad Sector, which included British, Dutch, and French Guiana, Saint Lucia, Aruba, and Curaçao.

In 1941, Bermuda, together with the Newfoundland and Greenland Base Commands, was put under General Headquarters. Its medical as well as its radiologic problems were the same as in all of the sectors of the Caribbean Defense Command, of whose medical installations only Trinidad warrants more than a few words of description.

Panama.—The radiologic service at the 333d Station Hospital (later the 262d General Hospital), Fort Clayton, Canal Zone, was operated by surgical and other nonradiologic personnel until April 1944, when Capt. (later Maj.) Maurice D. Frazer, MC, was appointed radiologist. He had excellent technical assistance from Army-trained technicians, who did capable, conscientious work. The workload averaged about 60 patients per day. Equipment was generally satisfactory, but fogging of films, by chemicals and heat, was a major problem until the Eastman tropical pack was introduced. Captain Frazer believed that there would have been much less trouble with films if they had been obtained locally instead of from the Medical Supply Depot at St. Louis.

Puerto Rico.—The usual type of radiologic care was capably provided at the 326th and 359th Station Hospitals by Capt. (later Maj.) Luis R. Perea, MC, and Capt. (later Maj.) Manuel G. Rodriguez, MC, whose fluent Spanish eliminated many difficulties that might otherwise have occurred with local patients.

Jamaica.—The radiologic service provided in Jamaica was of the infirmary type.

Saint Lucia.—In Saint Lucia and other islands of the Windward Chain, radiologic work was routine, most of it consisting of fractures and pneumonias. Patients requiring more elaborate diagnostic work were evacuated to the 41st General Hospital on Trinidad (p. 800).

The Guianas.—The radiologic care in both British and Dutch Guiana was of the type provided in the Windward Islands, with evacuation of patients requiring complicated diagnostic work to Trinidad.

French Guiana, on which some 6,000 civilian prisoners were incarcerated, proved to be a trouble spot. The 25-bed station hospital there was staffed with officers and enlisted men on detached service from Surinam (*5*). The X-ray technicians used the French equipment already installed and found it highly satisfactory.

Bermuda.—In Bermuda, where Lt. Col. Leslie M. Dobson, MC, served the 221st Station Hospital as radiologist from April 1941 to December 1945, the X-ray equipment arrived badly damaged, and his first task was to supervise its restoration. The field unit was delivered without a chassis, but a satisfactory wooden scaffolding was built in its place. For several months, the department had to operate with 10-ma. current because of the shortage of rotary converters to convert AC to DC current. The radiologic workload

was entirely routine; "all the interesting cases were promptly evacuated to the States."

Although these hospitals were widely separated, the problems in all of them were generally the same. They provided the infirmary type of service, which is always necessary but seldom interesting. Their most interesting patients were immediately evacuated to larger hospitals.

The standard equipment was the 30-ma. Picker field unit, which, with very few exceptions, performed well. The chief difficulty with equipment was that it was often broken in transit and that small, but often essential, parts were missing. Until tropical packing was introduced, fogging of films was a common complaint.

TRINIDAD

The Trinidad Base Command,[5] organized late in April 1941 at the Port of Embarkation, New York, consisted chiefly of a Coast Artillery unit of about a thousand men, supported by a 100-bed station hospital (the 359th) under the command of Maj. (later Col.) John A. Isherwood, MC, a Board-certified radiologist. The Army transport, the *American Legion*, which transported the troops and hospital personnel also carried a highly explosive cargo of bombs and high-test aviation fuel. Indoctrination of personnel en route included not only the important nature of the mission but also a warning against the vampire bats that live in hollow tree trunks and that were a menace to human beings as well as to cattle.[6]

359th Station Hospital

Facilities.—On arrival at Port-of-Spain, Trinidad, British West Indies, the troops were kept on board ship for 5 days until a tented hospital could be set up for use. This arrangement was necessary because it was the rainy season and some sort of cover was required.

The site selected for the hospital was at dockside, and, within a month of the arrival of the task force, a complete hospital had been set up with Quartermaster storage tents over wooden floors. The sides of the tents were extended, to provide circulation of air as well as protection from the continuing rains. Electricity was procured from Port-of-Spain. Later, a conventional, tropical-type hospital was provided.

Equipment.—The situation with respect to equipment was much less propitious. Through error or inexperience or too much haste, many essential

[5] The material for this section of this chapter was provided by Dr. Frederick W. Van Buskirk (formerly Major, MC), Dr. Nathan G. Gordon (formerly Captain, MC), and Col. John A. Isherwood, MC (Ret.).

[6] The indoctrination concerning the animal life of Trinidad proved inadequate. Bats did live in the eaves of barracks, and bars were necessary at night. Other fauna included boa constrictors (anacondas), a wide variety of other snakes, buzzards, voracious moths, grasshoppers 7 inches long, mongoose capable of killing snakes, tarantulas, and rats the size of rabbits.

items for the hospital, ranging from bedpans to mess equipment, were not transported with the troops and hospital personnel.

The X-ray department was particularly affected by the shortages. Not a single Army field unit was complete. A transformer was provided, with a control stand, a tube, two cables, and a safelight. But missing items included the X-ray table, the Bucky, the grid, and the tube stand. Darkroom supplies consisted of chemicals, films tropically packed, and one developing tray, but no tanks.

The first task of the radiologic personnel was to build a darkroom. This was done by erecting a frame 6 yards square, extending from floor to ceiling, around which blankets were tacked. A crude door was fashioned of blankets. The result was a room that was lightproof but was universally described as "infernally hot."

An X-ray table and stand were constructed of scrap lumber. The mobility of the tube stand was sacrificed for rigidity, and the table was therefore made considerably wider and longer than usual, so that the patient could be moved transversely and longitudinally in relation to the tube since the tube could not be moved in relation to him.

The only trays available in Port-of-Spain were the shallow porcelain kind. One was used for developer and one for hypo, and the single deep tray that had come with the X-ray equipment was used to rinse the films between developer and hypo and for the final rinsing. The water had to be changed very often, as did the developer, which heated up very quickly, especially in the available darkroom. A supply was kept in the laboratory icebox. With these precautions and with a careful check on the temperature of the solutions used, quite satisfactory films could be obtained.

The field unit worked very well, though care had to be taken to insure against breakdown of cables, which were vulnerable to humidity. The machine was seldom operated on voltages above 80 kvp. (kilovolt peak), especially on humid days. The cables were in short supply, and, when one broke, a machine might be out of order for as long as 3 weeks. It would be advisable in any future war to anticipate this difficulty by providing an extra cable with each field unit and to keep the supply depots well stocked with this vulnerable and essential part. Except for the cables, the machine was an excellent piece of equipment, rugged, readily transportable, and highly efficient for all kinds of work, including gastrointestinal and barium enema studies and intravenous pyelograms.

Ordnance personnel made the necessary repairs. It was frequently said that the machines operated more efficiently after the repairs had been made than they did when they were new.

Personnel. —The original hospital personnel consisted of nine medical officers, including a radiologist, one dental officer, one veterinary officer, and one MAC (later MSC) officer. The first radiologist was Lt. (later Maj.) Frederick W. Van Buskirk, MC, who served from the landing until November 1941. He was succeeded by Capt. Nathan G. Gordon, MC, who was not

a radiologist. Maj. (later Lt. Col.) Burton W. Trask, MC, succeeded Captain Gordon on 1 September 1942 and served until 29 January 1944. Capt. Oliver W. Welch, MC, was head of the service for the remainder of the war. When his duties permitted, Major Isherwood gave advice and assistance.

As soon as the lack of X-ray items was discovered, Major Isherwood had an inventory made and dispatched an airmail requisition to the supply depot in the Zone of Interior, describing the situation. At the end of 6 weeks, he was informed from the depot that, if his requisition were correctly made out and the numbers for the items in the supply catalog were attached in the proper arithmetical sequence, his request would be given prompt attention. Shortly afterward, the Surgeon, II Corps Area, under whom the task force was based for supply, visited the installation and took immediate steps to procure the necessary supplies. It was 5 months, however, before they all arrived.

Meantime, the department had been moved to a newly constructed wing of the hospital, where its facilities included a darkroom with running water, set off from the rest of the department by a wood partition and a door. Working conditions thus became more tolerable.

A standard tube stand and field X-ray table also replaced the improvised stand and table. A 5-gallon tank replaced the makeshift trays, but it was not refrigerated, and warm developer had to be siphoned off and replaced with developer from the icebox every hour or two.

The 15-kw. (kilowatt) gasoline generator which had arrived with the original equipment was never used, since current from town, though the voltage was uncertain and inconstant, was always available. The generator was loaned to the Engineers, and was never returned to the X-ray department.

The two technicians in the department had been trained under Colonel de Lorimier at Walter Reed General Hospital and were extremely competent. They had worked with the Army field unit and were of great assistance in setting up the radiology section.

Radiotherapy.—The field X-ray unit was also used effectively for superficial therapy, particularly for otitis externa and recurrent furunculosis, both of which were extremely common. The average output of the tubes was calibrated in the instruction book provided with the machine, which stated the r (roentgen) per minute, and was estimated at 100 kvp. 5 ma. at a given distance. To avoid the risk of cable breakdowns at this voltage, the treatments were given at 80 kvp.; but it was assumed that the output was what had been calculated at 100 kilovolt peak. The patients therefore received less than the calculated dose.

Workload.—In addition to the U.S. personnel cared for by the radiology service at the Port-of-Spain hospital, the department also examined men from the British Navy Air Training Center, from flattops when they were in port, U.S. Navy personnel, survivors from ships sunk by enemy submarines, and civilians. On one occasion, the department examined part of a British airplane, in a search for flaws in a vital area.

About 25 films and one or two fluoroscopic examinations were made daily. The findings were usually run-of-the-mill pneumonias and fractures, with an occasional peptic ulcer and an occasional case of tuberculosis. Survivors of submarine sinkings in the Atlantic were also investigated, usually to diagnose or eliminate pneumonia.

41st General Hospital

In October 1941, plans were drawn for a 1,000-bed semipermanent general hospital to be established at Fort Read, some 40 miles inland, near the town of Fernandez. The Surgeon General approved them, and building was begun in February 1942 and completed in October of that year. The site selected was originally jungle, heavily infested with malaria.

The hospital was built in two sections one with 900 beds and the other with 1,600 beds, though neither ever functioned to full capacity. The buildings were put up to face the trade winds, which blew through them and kept them cool and pleasant almost all of the time.

The X-ray department in this hospital was well planned. Space was ample, and the darkroom was conveniently located in the center, with radiographic rooms and offices around it. It was provided with 200-ma fluoroscopic and diagnostic units, both with shockproof cables, with exposed wires under the tables. The Westinghouse unit insulators were inadequate at the takeoff reel wire under the table. Because the humidity and use caused this reel wire to arc back, it could not be used. The General Electric unit had heavy insulators of a special type of glass, about 12 inches high, 3 inches at the base, and 2 inches at the top. The borders were serrated, with deep ridges. There was no arcing from these insulators.

A Picker field-type unit had a timer with a calk clutch, which dried out and shrank in the heat of the tropics. The trouble, located by a serviceman from Venezuela, ended when the clutch was replaced with one made of calk obtained from the laboratory.

The processing tank for the darkroom of the new hospital went down with a ship sunk by a submarine, but a local contractor built a substitute that functioned satisfactorily. One insert tank was provided, and a second was made of tropical, nondecaying local hardwood. Valves were handmade and adjusted to the water cooler. The time-temperature development technique was used.

Cassettes with Bakelite fronts warped, and poor apposition of screens resulted. The trouble was corrected by insertion of thin sheet wadding of the chocolate-box type between the Bakelite and the screen. All screens developed yeast mold except Patterson screens. Since the daily environmental temperatures were from 84° to 94° F., cooling was necessary for solutions, which had to range between 64° and 68° F.

Materials deteriorated rapidly in the tropical heat and humidity. If processing powder, for instance, was not used within 6 months, it simply ate out the tin cans in which it was put up.

The 41st General Hospital served, as already indicated, as a central hospital for the Caribbean Defense Command. It carried a heavy workload—between 6,000 and 7,000 patients during the 18 months of Major Trask's service in it.

The hard core of disease in the tropics, as the work in this hospital indicated, was malaria, which in many cases eventuated in rupture of the spleen. The first radiologic evidence of the rupture was blunting of the left costophrenic sinus by pleural reaction and fluid, with discoid atelectasis of the lung above the diaphragm.

Pulmonary tuberculosis apparently occurred only in troops already infected when they were sent to Trinidad. In these cases, the radiographs showed strands of fibrous tissue that had healed so firmly that they looked like banjo strings. Tropical bone abscess began in the skin, like a carbuncle, and penetrated into the bone, particularly the femoral bone. Kidney stones were uncommon. There was the expected incidence of ulcers, but gallbladder disease was extremely infrequent.

An interesting radiologic observation was that fractures in the native population healed with unusual rapidity. Fractures in U.S. personnel healed more rapidly than was usual in the United States, but not so rapidly as fractures in the native population.

BRAZIL [7]

Hospital facilities had to be set up in Brazil because, when the Air Transport Command was established in June 1942, its most important route was across the South Atlantic from Florida, across Brazil, and then across North Africa to Cairo. One of the important wings of this command was at Natal, Brazil, and the 194th Station Hospital was established there, with 100 beds (fig. 268). The 193d Station Hospital, of the same capacity, was established at Belém, Brazil, in January 1943 and the 200th Station Hospital, which served as the central hospital for U.S. Army Forces, South Atlantic, was established at Recife, Brazil, with 200 beds (fig. 269), also in January 1943.

The 100-bed 194th Station Hospital, which was sent to Natal in the middle of November 1944, had an X-ray department that served the entire command as well as the hospital. The radiologist, Capt. (later Maj.) John B. Cooley, MC, was the only trained radiologist in the command. Part of his experience had included instruction at the Medical Department Enlisted Technicians School at Billings General Hospital. The technicians who assisted him were trained in similar schools.

Equipment.—The hospital equipment consisted of two Picker portable field units, one of which was mounted on a Westinghouse Bucky table and was used for fluoroscopy and for gastrointestinal and barium enema studies as well as for other routine work. The other unit was set up in a semiper-

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[7] The material for this part of section II was provided by Dr. John B. Cooley (formerly Major, MC).

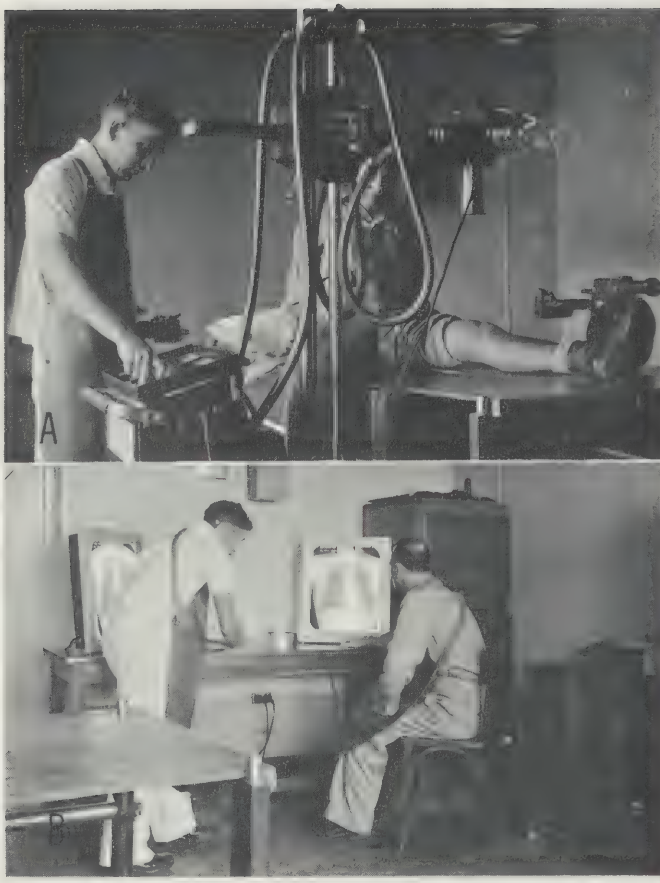

FIGURE 268.—X-Ray Room, 194th Station Hospital, Natal, Brazil, September 1944. A. Radiography. B. Radiographic interpretation.

manent position in an adjacent corner and was used for 6-foot examinations of the chest as well as for portable work.

A tank unit for the darkroom was requisitioned and was delivered by air; delivery by boat would have taken about 3 months. When it arrived, the difficulties experienced with the fluctuating temperature of the developing solutions were ended, though the processing had to be done by sight rather than by the standard time-temperature technique. The trouble arose because the water supply, which was partly from artesian wells and partly from the city water supply, was brought in in pipes which were either exposed or covered with very little dirt, chiefly sand. The sun therefore warmed the water by day, and, without protection, it was undesirably cold at night.

Because of the extreme heat during the day, the radiologist, even stripped

FIGURE 269.—X-Ray Room, 200th Station Hospital, Recife, Brazil, 1945.

to the waist, found it hard to tolerate the apron and gloves required for protection. Reading films during the day, when windows and shutters had to be kept closed in order to keep light from striking the view box, was entirely intolerable, and most readings were done at night, when windows and shutters could be opened and when there was usually an 8-mile wind.

Films.—When Captain Cooley arrived at the 194th Station Hospital, he found a stack of films, 4 feet high, waiting for interpretation and reporting, as up to this time there had been no radiologist in the entire command. When he found all the unexposed films apparently light fogged, and found no leaks in the darkroom to explain the trouble, he went through all the films in the bin and finally opened all the new packages. All the films were light struck.

He immediately requested 3 days' temporary duty in Recife, where, with the Quartermaster, he checked all the films in storage. There were no outdated films, but all of those developed at the 200th Station Hospital were also fogged.

With some difficulty, arrangements were made for the future delivery of all films by plane instead of by ship. With this plan in effect, there were no further difficulties. Films were always stored on end and great care was taken to use them in the proper rotation.

On one occasion, a representative from the Inspector General's office was horrified to find the films stored in wooden racks. This was, of course, contrary to Army regulations, which specify that all films shall be filed in metal

racks. Metal, however, was a very scarce commodity in Brazil, as Captain Cooley explained to the officer, and even wood was scarce in some areas. It would be difficult to correct the infraction of rules, since metal filing racks would be bulky equipment to fly in. He was allowed to keep the wooden racks after, as he expressed it, "frightening 2 years off the inspector's life when I picked up a film and held my cigarette lighter under one corner." "Naturally," Captain Cooley continued, "there was no flame from the film, no explosion, and no deadly fumes."

Workload.—In Natal, there were some 5,000 military personnel and the same number of civilians, chiefly natives, engaged in duties directly or indirectly connected with the Parnamirim Airport. Natal was the jumping-off place for Africa and the Far East, and in July, August, and September 1945 there were as many as a thousand flights daily in and out of this airport. In addition to its routine duties, the hospital had to be prepared to handle a minimum of 80 casualties if C–54's should crack up. The emergency, fortunately, never came to pass, but many hours were spent planning for it, including corridor traffic patterns and practice. All personnel walked through the entire plan many times before the first Green Project planes landed at Parnamirim Field.[8]

Since Captain Cooley was the only radiologist in the command, films were sometimes flown to him from the 175th Station Hospital on Ascension Island (fig. 270) and the 193d Station Hospital at Belém. On one occasion, he received a tightly sealed, TOP SECRET 14- by 17-inch envelope, containing the radiographs of the chest of a high-ranking officer: they showed bilateral pulmonary tuberculosis. A second, similar experience concerned films from the detachment of U.S. Navy personnel at Natal, which had its own medical officer but no radiologist. Captain Cooley was asked to X-ray a dental technician, whose nocturnal coughing was keeping his whole barracks awake. The test film showed bilateral pulmonary tuberculosis with cavity formation, and the laboratory had no difficulty in isolating acidfast bacilli in the sputum. The technician was immediately evacuated to the Zone of Interior, and the rest of the detachment was X-rayed by Captain Cooley and his technicians, fortunately with negative results.

Once a month, Captain Cooley was sent to theater headquarters at Recife, about an hour's flight from Natal, in a C–47, for 3 days' temporary duty, to conduct fluoroscopic examinations and to settle any other radiologic problems that might have arisen since his last visit.

The routine work at Natal was equivalent to that of any station hospital in the Zone of Interior. It covered permanently based personnel, numerous transient flying personnel, and, occasionally, German or Italian prisoners of war who had been brought in after surface raids or submarine sinkings.

[8] Green Project, which was the Air Transport Command program for bringing some 50,000 passengers a month from Europe to the Zone of Interior, began officially on 15 June 1945. Originally, the passengers were to be troops coming home for rest leave before being redeployed to the Pacific. The route followed by Green Project planes was Casablanca, Dakar, Natal, Belém, British Guiana, Trinidad, Puerto Rico, and Miami.

FIGURE 270.—X-ray room in surgical building, 175th Station Hospital, Ascension Island, 1945.

LIBERIA

Hospital equipment and personnel for the 25th Station Hospital departed from Charleston, S.C., in May 1942 and arrived off Liberia in mid-June. The hospital, which was set up at Marshall, Liberia, close to the Firestone Tire and Rubber Co. plantation, began in tents, without any electricity. It took about 6 weeks for the material for its construction and equipment to be unloaded in lighters supplied by the Firestone plantation. By early September, a wooden, tropical-type hospital had been constructed, but it was some time before wiring was attached for the X-ray unit to operate. Current was first supplied by a gasoline generator and then from a central source. Until it was supplied, the radiologic work was done at the Firestone Hospital, 20 miles away.

The head of the radiologic service, Capt. James M. Pair, MC, was not a trained radiologist, but he operated a highly efficient department, well laid out physically, and with competent technicians whom he trained himself. During his tour of duty, from June 1942 to February 1944, the 30-ma. field unit in the department was the only X-ray machine in Liberia except the one at the Firestone Hospital.

The X-ray department at the 25th Station Hospital cared for the personnel of Roberts Field, near Monrovia, Liberia, seamen from torpedoed ships, usually British, and Liberian personnel.

The field X-ray unit operated most efficiently except for the special atten-

tion required by the cables in a location 5 degrees above the Equator, where the humidity was very high at all times and the rainy season lasted 7 months. There were not many breakdowns, but, when they occurred, since there was no maintenance service available, repairs were not always made according to the instructions in the manual.

The temperature of the solutions in the darkroom required the same careful attention in Liberia as elsewhere in the tropics. In this connection, an experience in another part of Africa might be related. When Lt. Col. (later Col.) Kenneth D. A. Allen, MC, was on his way to the European theater to assume his duties as Senior Consultant in Radiology in that theater, his plane put down at Accra, Gold Coast, for refueling. The senior medical officer at the installation, who had recognized his name on the passenger list, asked for his help because the films being produced at the hospital (the 67th Station Hospital) were so dark and fogged they could scarcely be read. They were developing them, he said, at a temperature of precisely 65° F., and that was precisely the reading shown when the thermometer was taken out of the tank. When Colonel Allen examined the thermometer more closely, however, he saw that, probably because of the extreme heat, the mercury had separated, and the thermometer was useless. No other thermometer was available, but the temperature of the solution, to the hand, seemed at least 85° to 90° F.

BURTON W. TRASK, M.D.

Section III. The Middle East and Persian Gulf Commands [9]

This section of this chapter concerns radiology in World War II (1) in the Middle East command, which included Egypt, the Sudan, Libya, Eritrea, Palestine, Arabia, and Syria, and (2) in the Persian Gulf Command, which consisted of the gulf, desert, and mountain districts of Iran (*6, 7*).

The story of radiology in North Africa (Algeria, Tunisia, Morocco) is told in detail in chapter IX of this volume, dealing with the Mediterranean theater (p. 237). There is little to tell of radiology in the remainder of the African Continent. U.S. medical activities in this vast area were limited to small, scattered, and relatively minor installations set up by the ATC (Air Transport Command). The medical service provided in them was chiefly of the dispensary type. Only occasional installations had any X-ray equipment

9 (1) The U.S. North African Military Mission was discontinued on 17 June 1942, and USAFIME (U.S. Army Forces in the Middle East) was established in its place. On 15 September 1943, Headquarters, USAFIME, was expanded to include Headquarters, USAFICA (U.S. Army Forces in Central Africa). Effective 1 March 1945, USAFIME was further expanded to include Northwest Africa and was redesignated AMET (Africa-Middle East Theater). (2) Effective 13 August 1942, the Iran-Iraq Service Command was redesignated the Persian Gulf Service Command. The Persian Gulf Service Command was under the War Department for operational purposes and under USAFIME for administration and supply. It came under Services of Supply, USAFIME, when the latter was activated on 4 November 1942 and resumed its former status under USAFIME on 20 January 1943. On 10 December 1943, the Persian Gulf Service Command was relieved of its attachment to USAFIME, became a separate theater directly under the War Department, and was redesignated the Persian Gulf Command.

FIGURE 271.—38th General Hospital in desert near Cairo, Egypt.

(field units), and very little radiologic service was therefore provided. Patients with major illnesses or injuries were sent to the 38th General Hospital in Egypt.

THE MIDDLE EAST COMMAND

The first U.S. troops to arrive in force in the Middle East were landed in Egypt in October 1942, from the *Aquitania*, after a voyage of 42 days from the east coast of the United States around the Cape of Good Hope, through the Indian Ocean and the Suez Canal.

There was considerable initial confusion about the use of these troops. They arrived during the Battle of El Alamein. If Egypt were held, the chief U.S. base would be near Cairo. If it were lost, then base installations and major medical facilities would be set up in Palestine, Eritrea, and Iran. As a matter of fact, the Battle of El Alamein proved decisive. The outcome directly shaped the medical and radiologic history, as well as the military history, of the war in the Middle East. Egypt became the center of the command, with Cairo as its headquarters.

Even before the 38th General Hospital landed, its construction had been begun at Darb Al Hājj, a minuscule settlement in the Sahara about 12 km. from Cairo, which was occupied by a U.S. post, Camp Russell B. Huckstep. The hospital did not occupy its quarters (fig. 271), however, until Rommel

was in full flight from El Alamein, after which active fiighting in Africa was confined to Tunisia, Algeria, and Morocco.

For a time, the 4th, 15th, and 16th U.S. Field Hospitals served U.S. service troops, the Ninth Air Force, and the Air Transport Command in the Middle East. Their chief function was to supply emergency treatment and then to evacuate the sick and injured as rapidly as possible to the 38th General Hospital. Each hospital was split into three platoons, each of which was a functioning unit.

These field hospitals were bivouacked in unlikely places, once in a gutted airport in Tobruk, once at an Italian zoo near Benghazi. They operated in standard Army tents, erected over excavations from 3 to 4 feet deep and so heavily sandbagged that patients and medical personnel were safe except from direct hits. Each platoon had a single tent for X-ray laboratory, and dispensary purposes. There were no radiologists attached to the platoons, and their X-ray equipment was limited to field units.

The 38th General Hospital supported the Air Force units in North Africa and Sicily. Station hospitals were set up in Tel Litwinsky, Palestine; Asmara, Eritrea; and Khartoum, Sudan. A few field hospitals and a great many dispensaries were scattered through the remainder of the Middle East.

THE PERSIAN GULF COMMAND

The Persian Gulf Command was established for a single purpose, to supply materiel to the Soviet Union. In all, approximately 30,000 U.S. troops were sent to Iran to deliver supplies through this corridor. Over a period of 3½ years, from 1942 to 1945, some 5 million tons of supplies were delivered, enough to maintain 60 combat divisions (*7*). The supplies were landed in Persian Gulf ports and transshipped by truck convoys to the Soviet Union over the vast Iranian plateau.

Army posts were established for rest and repairs along the convoy route at the following places in Iran: Ahvāz, Andimeshk, Khorramābād, Hamadān, and Kazvin, where the Soviet zone began. During the entire war, there was only one general hospital in the command, the 113th, which arrived in Ahvāz on 11 May 1943 as a 750-bed station hospital and was converted on 7 September 1943 to a 1,000-bed general hospital. This hospital supported the station and field hospitals located at the Army posts along the convoy route, and also received patients from units in Tehrān, Sultānābād, and elsewhere in Iran.

PERSONNEL AND TRAINING

Staffing

The original tables of organization for general hospitals called for three radiologists, in the respective ranks of major, captain, and lieutenant. The 38th General Hospital was duly organized with this number, but one radiolo-

gist was transferred out of the unit before it left the United States and another was transferred to Italy from Egypt within a year after the hospital was established. At no time thereafter was there more than one radiologist on duty. Similarly, there was never more than one radiologist assigned to the 113th General Hospital in Iran.

Since neither of these hospitals was ever exceedingly busy, a single radiologist could easily handle the work in each. The 38th General Hospital averaged 10,000 admissions a year, about 5,000 of which required diagnostic X-ray examination. In a typical week, there were between 25 and 30 gastrointestinal and barium enema studies, and from 70 to 80 examinations for other purposes. Combat casualties were few and were far outnumbered by various accidental injuries such as those caused by jeep accidents or falls into slit trenches.

There was general agreement in both the Middle East and the Persian Gulf commands that two radiologists would have been sufficient in each general hospital, even if combat casualties had been numerous, which they never were. A table of organization providing for a lieutenant colonel and a captain was considered logical.

It was neither practical nor necessary to staff each of the station and field hospitals in these commands with radiologists, but regular trips to them by radiologists assigned to the general hospitals would have been helpful and would have resulted in better and more economical radiologic service than was always provided in them.

Since even in general hospitals radiologists were not fully occupied with their radiologic duties, nonradiologic assignments were to be expected. They ran the entire gamut of medical and administrative chores. Maj. (later Lt. Col.) Edgar L. Dessen, MC (fig. 272), at the 38th General Hospital, at various times served as ward officer for the officers' medical ward; librarian; auditing officer; inspection officer; officer in charge of the reconditioning programs for officers and enlisted men; adjutant; executive officer and detachment commander. Radiologists in smaller hospitals had even more varied duties, including, in at least one instance, that of latrine inspector. The multiple duties were usually accepted without complaint and regarded as interesting rather than onerous in view of wartime requirements.

Training

Maj. (later Col. Melvin A. Dillman, MC, of the 38th General Hospital, was the only Board-certified radiologist assigned to either the Middle East or the Persian Gulf Command during the war. This hospital had been formed from medical personnel at Jefferson Medical College of Philadelphia Hospital. Several other radiologists in these commands had been called out of their residencies as activated Reservists and had had certain amounts of formal radiologic training. Major Dessen and Capt. Paul S. Friedman, MC, also from Jefferson Medical College of Philadelphia Hospital, were in this cate-

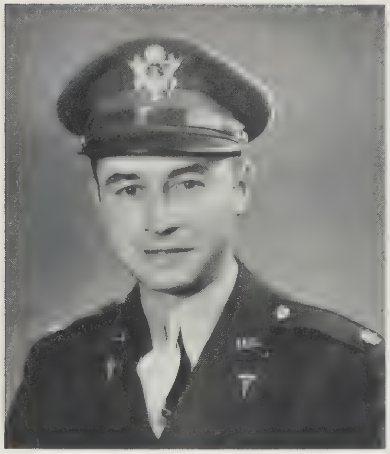

FIGURE 272.—Maj. Edgar L. Dessen, MC, radiologist, 38th General Hospital.

gory. Other medical officers who served as radiologists in smaller hospitals in the commands had no training in this specialty before the war. Apparently, anything in their 201 files that connected them with radiology, however remotely, was sufficient to dictate a radiologic assignment. Thus, Maj. (later Lt. Col.) Edgar S. Weaver, MC, 21st Station Hospital, who did such a superb job in the distribution of X-ray equipment both in Iran and in Egypt (p. 815), had had 2 years' experience in a tuberculosis hospital when he was a medical student. Similarly, Capt. William H. Rosenblatt, MC, who was radiologist at the 104th Station Hospital in Eritrea, had done chest fluoroscopy as part of the routine workup of patients in a tuberculosis clinic. Capt. John Siddal, MC, who served in the Sudan, was interested in photography. Still other radiologic officers were primarily interested in other specialties or were general practitioners.

These untrained, ersatz radiologists performed remarkably well under difficult circumstances, considering their lack of any training, the paucity of reference books and journals, and the absence of any formal program of radiologic consultation in either command.

On the other hand, many errors were made in the interpretation of films. A patient with hypertrophic changes of the spine, for instance, was put into a body cast for a supposed fracture of the hip. Gas in the stomach was interpreted as a subphrenic abscess or a ruptured viscus. Accessory bones and suture lines in the skull were diagnosed as fractures. Aortic knobs became mediastinal tumors. Pectoral shadows were diagnosed as pneumonia and azygos lobes as tuberculosis.

No irreparable harm was done because of these errors, since practically all the patients were sent to the general hospitals for disposition board pro-

ceedings, in the course of which most mistakes were corrected. The correction, however, involved considerable inconvenience for the patients and considerable cost for the Government.

Rank

As in all other theaters and areas, lack of opportunities for promotion was a perpetual source of discontent among radiologists. There were three majors in the Middle East and Persian Gulf commands, two of them at the 38th General Hospital in Egypt. All the rest were captains. Under the existing table of organization, none of these men had any real chance for promotion. If a vacancy did occur in the field, it was likely to be filled by an officer from headquarters in Cairo or Tehrān, by the simple expedient of placing him on detached service in the field while retaining him at headquarters.

Numerous radiologic officers were never promoted. Capt. (later Maj.) Maurice N. Harris, MC, for instance, served competently for almost 3 years in Iran in the same rank. He admitted that this was a matter of some concern to him but wrote (in 1959) that he found considerably more irritating the use of stationery in the peaceful, comfortable and metropolitan headquarters at Teherān imprinted "In the field, Teheran." With others, the lack of promotion was also an irritant, not a major morale problem.

Rotation

Rotation became effective in 1945, but was entirely academic in both the Middle East and the Persian Gulf commands. No trained radiologists were supplied as replacements, since the activities in both areas were rapidly decreasing. The few radiologists in excess had been redeployed to Italy or India long before. When the war ended, Major Dessen was the only U.S. radiologist on the entire African Continent. He had served there for 33 months.

Technicians

When the 38th General Hospital arrived in Egypt, in 1942, it had four technicians, two of them staff sergeants, one a sergeant, and one a corporal. Each of the larger hospital units in the command also had at least one trained technician. These men were all Army-trained, and no word of criticism was ever heard concerning their training and abilities.

Technicians, however, were usually in short supply in Iran. Four trained men arrived late in 1942; but, after they had been unassigned for several months, except briefly to the 18th Field Hospital, all applied for Officers' Candidate School and all were accepted. Thereafter, most technicians were trained on the job, chiefly by Captain Friedman, at the 113th General Hospital, and Captain Harris, at the 19th Station Hospital. The training

included lectures on physics, anatomy, and physiology, and practical demonstrations of X-ray technique. The USAFI (U.S. Armed Forces Institute) correspondence course in physics was put to good use, as was the Army X-ray manual.

Liaison

The wide distances between Army installations in the Middle East and Persian Gulf commands prevented much liaison between U.S. radiologists. Relations with our British allies were, however, uniformly amicable and mutually helpful. Before the 38th General Hospital began to function, Major Dessen had very close relations with the staff of the 15th Scottish Hospital in Cairo, in which X-ray studies were done on U.S. troops. He also had a close relation with Squadron Leader Forbes Rees-Jones, radiologist for the Royal Air Forces Hospital in Heliopolis, Egypt, with whom he consulted frequently on interesting cases. The relations included loans of items in short supply and substitution for each other for detached duty or leave. U.S. medical officers frequently attended British hospital scientific meetings and social functions, and vice versa. The same situation prevailed throughout the command, as well as in Iran, where the British were usually represented at U.S. monthly staff conferences.

U.S. relations with civilian physicians and radiologists in locations near U.S. hospitals were equally good. Egyptian, Sudanese, Eritrean, Iranian, Palestinian, and Syrian physicians all freely exchanged information with their U.S. counterparts, and many interesting and unusual cases of tropical disease were observed as a result (p. 821). The Italian radiologist in the hospital at Massawa, Eritrea, which was taken over by the 104th Station Hospital, was extremely helpful. In short, in both the Middle East and the Persian Gulf commands, the practice of radiology, like that of the rest of medicine, transcended international barriers.

FACILITIES AND EQUIPMENT

Distribution

The 38th General Hospital in Egypt, a 1,000-bed hospital, occupied a number of detached, one-story buildings, extending over half a mile, and constructed in the fall of 1942 for hospital purposes (fig. 271). The buildings were made of desert sand block. A long row of medical wards extended eastward, and a similar long row of surgical wards extended westward. Between these rows were a number of individual buildings used exclusively for X-ray, laboratory, and dental departments, administration purposes, and messhalls.

The X-ray building (fig. 273), 90 feet long, which had a hall running through its entire length, opened flush onto the paved sidewalks provided

FIGURE 273.—X-ray building, constructed of desert sand block, at 38th General Hospital.

throughout the hospital area. There were five completely equipped diagnostic rooms; a room for superficial therapy; a large, well-equipped processing room with a labyrinth; and three separate offices, one for the radiologist, one for the technicians, and one for reporting and consultation. Sheet lead shipped from the Zone of Interior was used wherever protection was indicated.

Two of the diagnostic rooms at this hospital were equipped with stationary 100-ma. tilt table, motor-driven Picker units (fig. 274). Two others were equipped with Picker field units, and the fifth room was equipped with a Keleket portable unit. There were two urologic tables, one provided with a Picker field unit, the other with a 100-ma. unit (fig. 275).

The processing equipment was General Electric, new, modern, and entirely satisfactory (fig. 276). The water temperature in the tanks was thermostatically controlled, and the camp water supply, after some initial dry runs, proved adequate. An electric film drier was available with a sufficient number of hangers. There were enough cassettes of all sizes, all in good condition. Four individual fluorescent illuminators were provided for the radiologist's office, and there were others elsewhere in the X-ray department and in other locations in the hospital. Other accessory equipment included two Lysholm grids for studies with the portable unit and for erect examination in the department.

Since the camp had a central power system, there were none of the difficulties that often occurred with gasoline generators, except during an unusual central failure.

FIGURE 274.—Stationary Picker unit (100-ma.) in general radiographic room, 38th General Hospital.

The volume of work at the 38th General Hospital never warranted the equipment provided in the X-ray department, and within a short time one of the portable units was placed nearer the medical and surgical wards so that the long trek from department to wards for portable studies would be eliminated.

It would be pleasant to report that all medical installations were as richly endowed radiologically as was the 38th General Hospital, but of course they were not. The 113th General Hospital in Ahvāz, for instance, was housed in a considerably smaller building and had only one large 100-ma. unit and two field units. Field equipment was used in all other hospitals in both commands except at Asmara, Eritrea, where the Army occupied a hospital which had originally been built for the Douglas Aircraft Co. when plans had included a repair base for planes in this location. The hospital, which was staffed with civilian physicians, was occupied by the company for only a short time and was repossessed by the Army after the plans were changed. It had a functioning X-ray department, equipped with a 100-ma. tilt-table General Electric unit.

During 1942 and 1943, X-ray equipment was poorly distributed in both the Middle East and the Persian Gulf commands for several reasons. At the 4th Medical Supply Depot in Egypt and the 21st Medical Supply Depot in

FIGURE 275.—Urologic unit and 100-ma. unit in radiographic room, 38th General Hospital.

Iran, a good deal of X-ray equipment was either not listed at all or listed incorrectly because the supply officers could not identify particular pieces. They were therefore unwilling to issue anything or they issued material which did not match the items requisitioned. The result was that some hospitals had inadequate equipment, some had equipment that could not be used because parts were missing, and some had excess equipment.

In the fall of 1943, when Col. Eugene W. Billick, MC, Chief Surgeon, USAFIME (U.S. Army Forces in the Middle East), and his supply officer, Maj. Andy V. Little, PhC, visited the 21st Station Hospital, Khorramshahr, Iran, on a routine inspection trip, Major Weaver, the radiologist, told them bluntly that the X-ray equipment in the command was poorly distributed. In accordance with military custom, he was immediately detached from the 21st Station Hospital to correct the situation of which he had complained.

Major Weaver's first step was to inventory the equipment in the 21st Medical Supply Depot and catalog it correctly. He then visited every hospital in the command and inventoried all of its X-ray equipment. In his report, he recommended that excess equipment in all hospitals be shipped back to the supply depot and that missing items be requisitioned. He also pro-

FIGURE 276.—Developing room at 38th General Hospital.

vided a relatively short list of equipment to be requisitioned from the Zone of Interior. Major Weaver's recommendations were followed to the letter, and there were no more radiologic distribution problems in Iran.

In September 1943, Major Weaver was placed on detached service at Headquarters, USAFIME, Cairo, to perform the same function for the Middle East command. He followed the procedure he had used in Iran. Again his recommendations were followed. Some excess equipment returned to the 4th Medical Supply Depot was shipped to the 21st Medical Supply Depot for redistribution in Iran. Some was shipped back to the Zone of Interior, including a 100-ma. standard diagnostic unit and a superficial therapy unit originally brought to Eritrea for the Douglas Aircraft Co. and now in need of repairs.

Major Weaver's performance was outstanding and is particularly noteworthy because he was not a trained radiologist but a medical officer assigned to radiology.

As wartime activities decreased in the Middle East and Persian Gulf commands in late 1944 and 1945, medical units were transferred to other theaters and usually took their X-ray equipment with them. Later in the war, the units still in these commands began to ship their equipment back to the Zone of Interior. In March 1945, the 38th General Hospital returned one of its 100-ma. diagnostic units as well as its portable Keleket unit.

Special Items

There were seldom any complaints about the stationary X-ray units provided in the larger hospitals. Considering the rough usage to which the Picker field unit was subjected, its performance was generally regarded as superb. It was rugged and easily transportable. It required a minimum of maintenance and repair. It gave good service in installations ranging from general hospitals to dispensaries, and it was equally suitable for departmental and bedside use.

The Picker unit was assembled for fluoroscopy with the fluoroscopic screen (item 96145) and for radiography with the portable grid (item 96070).

The lightproof tent (item 96175) was eminently satisfactory for processing films but extremely unsatisfactory when it was used for fluoroscopy. The tent was quite small, and, when it was filled with processing and fluoroscopic equipment and occupied by radiologist, patient, and technician in areas of extreme heat, conditions became intolerable. It was acceptable for darkroom purposes when erected within a building or within a larger tent, but again heat was a major objection. Separate tents for processing films and for fluoroscopy would have improved matters.

Processing equipment, including the film bin, drier, and loading bench combination (item 96055), was durable and satisfactory (fig. 276). It seldom needed repair, and it operated well under the varying climatic conditions encountered in both commands. Its complete efficiency, of course, depended upon an adequate supply of running water, which was not always available in mobile field units in Libya and Iran.

The master chemical section of the processing unit (item 96115) proved both practical and durable. The necessary chemicals usually arrived in good condition.

Only the two general hospitals had electric film driers. Sooner or later, most hospitals received one or two fluorescent illuminators.

The gasoline generator was often a problem. In field hospitals and some station hospitals, it was the only source of electric power and was used to light both the interior and the exterior of the hospital. In addition to the difficulties with the power supply that resulted, the duststorms in Iran and the sandstorms in Egypt did a great deal of damage. These storms were thick, suffocating, stifling fogs. The dust and sand permeated the smallest crevices, and, within a few minutes after a storm had started, equipment looked as if it had stood unused for years.

Generators were usually located in the open, where various methods were used to protect them. Sometimes small sheds were built. Protective drapes of heavy cloth, plastic, and other materials were also used, but, in spite of all efforts, the generators frequently became badly clogged, and extensive, repeated cleaning was necessary.

Improvisations

Shortages of various items were overcome in both commands by improvisations:

When X-ray departments of small hospitals operated in tents, as some did for fairly long periods of time, a concrete slab was poured for flooring, to facilitate movement and operation of portable X-ray units.

In semipermanent installations, field units were equipped with tabletops constructed of Masonite or plywood.

Early in the operation of both commands, cassettes were in pitifully short supply. The 154th Station Hospital in Hamadān, Iran, had a single 11- by 14-inch cassette that had been loaned to it by an Indian radiologist. Until more cassettes were provided, 14- by 17-inch films were cut down to fit this cassette and smaller films were fitted into the corners. In other units, various similar improvisations were resorted to. Thus, cardboard holders were used in many hospitals until cassettes arrived. Almost every hospital had a vertical cassette holder made of plywood. It was used chiefly for chest radiography and, with panel cutouts, for radiography of paranasal sinuses, the cervical spine, the skull, and other special studies (fig. 277). Dental and occlusal film holders were also improvised.

When film was scarce, as it sometimes was, larger films were cut to small sizes. Dental films were often improvised in this fashion, or small lead cutout diaphragms were used.

Homemade furniture was used in all radiology departments and in the radiologists' quarters (fig. 278).

Captured Equipment

In Tehrān, Iran, the British had taken over a German-built hospital that they were operating as a military hospital. It contained a portable Siemens X-ray unit, which was compact, highly efficient, and so light that it could easily be handled by one person. This unit was used temporarily by Captain Harris at the 154th Station Hospital.

An Italian hospital at Massawa was captured by the British, who permitted the 104th Station Hospital to occupy it from February to June 1943. The equipment included an upright fluoroscopic unit and a fixed horizontal table unit, both excellent pieces of equipment, according to Captain Rosenblatt, the radiologist. The helpfulness of the Italian radiologist at this hospital has already been mentioned.

FILMS

After the first few months, there was no shortage of X-ray films at either the 38th or the 113th General Hospital. Occasionally, the films would arrive

FIGURE 277.—Field X-ray unit in radiographic room at 38th General Hospital. Note improvised cassette holder, with cutout for sinus and mastoid examinations.

damaged by heat, light, moisture, or all of these factors. This did not happen often, perhaps because the supply officer had a tendency to send the most presentable boxes to the larger hospitals.

In other hospitals, the situation was distinctly different. They were located in desert areas, or in areas of extreme heat, and delivery of the perishable items to them was a major logistic problem. The difficulty was compounded by damage done to films by storage in warehouses and depots at very high temperatures. In Iran, it was the exception to receive films clear and entirely undamaged. Most films were discarded because they were completely black or so dark as to be entirely unfit for use. It was often necessary to use films of varying shades of gray. It became the practice to develop samples of the films in each package as soon as it arrived, to determine whether they were usable.

Films that were unusable for X-ray purposes were at a premium for other uses. Cleared of emulsion, they were used to cover hospital charts, bulletin boards, signs, and many other items. They were in great demand for

FIGURE 278.—Radiologist's quarters at 38th General Hospital, showing furniture made of packing crates.

repairing broken windows of hospital buildings and broken windshields of jeeps and trucks. Many open jeeps were converted into sedans with tops made of scrap material and windows made of discarded X-ray films.

Disposition of radiographs.—It was the general policy in both commands to send films with patients when they were transferred from one hospital to another or evacuated to the Zone of Interior. This practice was begun by the 15th and 16th Field Hospitals, which followed the British Eighth Army in the western desert in October and November 1942 (p. 808), and was continued thereafter. One report was filed with the films that accompanied the patient, and a duplicate was kept in the alphabetical files in the X-ray department.

Many hospitals kept their films in empty packing creates. This arrangement provided both convenient storage and excellent mobility. When the hospital moved, the tops were nailed on the cases and the films moved with the utmost expedition.

PROTECTION

At the 38th General Hospital, as already mentioned, all the walls of the X-ray rooms were completely lead lined. From this acme of perfection, there were various gradations of lesser protection in smaller hospitals. For an inordinate time the 113th General Hospital and the 21st Station Hospital in Iran had no lead sheeting, but an adequate supply was finally secured in 1944.

The field fluoroscopic unit was the greatest source of radiation exposure, and, while it was in use, lead aprons were regularly worn by radiologists and technicians. The radiologist wore lead gloves during fluoroscopic examinations. Every installation had at least one lead protective screen, and technicians were trained to use it during radiography. In tented departments they wore lead aprons while making radiographs.

The inherent filtration of the field unit tube was about 0.5 mm. A1, and additional filters were seldom used. The 100-ma. units in the larger hospitals had additional 1 mm. A1 filters.

Large fields were seldom used in superficial X-ray therapy. There was adequate lead sheeting for the protection of patients, and lead lined screens protected the operators.

X-ray personnel wore dental films for radiation monitoring. Films were also used to test the walls of X-ray departments. Blood counts were done on all personnel every 6 to 12 months.

CLINICAL CONSIDERATIONS

Combat Injuries

Combat injuries were only occasionally seen in the hospitals of the Middle East and Persian Gulf commands and presented no special problems when they were encountered. One exception might be mentioned: In 1944, a group of Indian soldiers brewed tea in the center of a railroad car that was part of an ammunition train standing in the depot at Ahvāz. In the explosion that inevitably followed, dozens of men received multiple metallic foreign objects of all sizes and shapes in all parts of their bodies. Captain Friedman, radiologist at the 113th General Hospital, worked overtime to localize these objects; it was a highly unusual, concentrated use of a special technique.

Diseases

Since war wounds presented no problems in the Middle East and Persian Gulf comands and other injuries presented only the problems usually encountered in civilian radiology, they need no further comment. The clinical discussion in this chapter is limited, therefore, to the radiologic aspects of certain tropical and subtropical diseases encountered in these commands. All of these conditions are discussed in detail in other volumes of this series (*8*, *9*, *10*, *11*, and *12*).

U.S. troops were immunized against many of these diseases and, fortunately, seldom developed the others. The potentialities for trouble, however, were always present, and it was important for all medical officers, including radiologists, to become acquainted with unfamiliar diseases and with unusual manifestations of familiar diseases.

Most of the patients observed were natives, who were seen with the cooperation of local physicians in the two commands. The Kasr-El-Aine Hospital in Cairo, in particular, was a veritable museum.

No manifestations demonstrable by radiologic techniques were observed in a number of diseases, including cholera, yellow fever, sandfly fever, and dengue fever, in which roentgenograms of the affected joints were invariably negative. In helminthic diseases, chiefly hookworm, which is discussed in detail in chapter XXXV, entitled "China-Burma-India Theater," (p. 758) native physicians, like U.S. radiologists, could not recall ever having observed barium in the intestinal tract of any of the worms responsible for the infections. Filariasis, so far as is known, was not observed in U.S. troops in either Africa or the Persian Gulf Command but was occasionally seen in soldiers returned to the United States.

Radiologic manifestations were observed in the following diseases in the two commands:

1. Hepatomegaly and splenomegaly were frequent in smallpox, which was omnipresent among natives.

2. Bronchitis and bronchopneumonia, as well as nephritis, were frequent and often fatal complications of typhus. Endothelial proliferation in the smaller vessels was part of the pathologic process.

3. Bubonic plague was characterized by visceral congestion and considerable splenomegaly. The pneumonic variety of plague was characterized by intense pulmonary congestion, involving whole lobes, and enlargement of bronchial and hilar lobes.

4. Leprosy was highly endemic in Equatorial Africa but was never contracted by U.S. personnel. In the large leprosarium in Upper Egypt, many roentgenograms were studied showing bone atrophy and destruction, frequently with loss of digits and with bony deformities.

5. In leptospiral diseases, such as Weil's disease and epidemic jaundice, the pathologic process included hepatomegaly with areas of degeneration and focal necrosis; swelling of the kidneys and degenerative changes in the convoluted tubules; and, in some instances, associated bronchopneumonia.

6. Lymphogranuloma venereum was characterized by superficial and deep lymphadenitis that gave rise to suppuration and fistula formation that terminated in healing with extensive scar tissue. A late sequela of roentgenologic importance was rectal stricture.

7. Malaria, which was notably frequent in Air Transport Command personnel, was of little radiologic importance except for varying degrees of splenomegaly. In the acute variety, the spleen was congested and soft, and traumatic or spontaneous rupture might occur.

8. In relapsing fevers of spirochetal origin, areas of infarction were demonstrable in the liver and spleen, with enlargement and parenchymatous degeneration. Pneumonia was a frequent complication in fatal cases.

9. In hydatid disease, which was particularly frequent in Egypt, encysted parasites were observed in the liver and lungs, after the ingested ova

FIGURE 279.—Splenomegaly, with depression of left side of colon. This type of splenomegaly was frequently observed in leishmaniasis.

had hatched in the duodenum and penetrated through the wall to enter the bloodstream, whence they were chiefly filtered out to these structures. The unilocular type of cyst slowly but steadily enlarged in a single area, with resulting pressure symptoms. The alveolar type, which resembled a sponge on section, was a metastasizing growth that spread by direct extension to surrounding tissues and sent daughter cysts through the blood and lymph streams to other sites. Hydatid cysts could cause extensive bony destruction. They were not uncommon in the lungs and brain but were most frequent in the liver, where they sometimes became calcified and produced bizarre and dramatic radiologic findings. Two patients with calcified cysts were observed at the 38th General Hospital, and two others have been since the war in the writer's private practice in Pennsylvania.

10. The variety of leishmaniasis known as kala-azar (also as Dumdum fever and tropical splenomegaly) was particularly prevalent in Egypt, where it chiefly affected children. Multiplication of parasites within the reticuloendothelial cells caused extreme splenomegaly (fig. 279), usually associated with some hepatomegaly. Both organic enlargements were accentuated by the emaciation that accompanied the disease. Roentgenograms taken in these cases showed some of the largest splenic shadows on record.

11. Brucellosis in the Middle East caused the splenomegaly and lymphadenopathy commonly observed in this disease in the United States. In

addition, small areas of confluent lobular pneumonia were observed in several cases in Egypt.

12. In one instance of cestode infection caused by cysticerci of *Taenia solium* observed at the 38th General Hospital, characteristic calcific subcutaneous nodules could be visualized by soft-tissue studies. Cysticerci were always kept in mind in patients with suspected epilepsy and brain tumors, but they were not identified in any case.

13. In dracunculiasis, if the parasite was not completely removed when it presented at the skin surface of the lower leg or foot, partly or completely calcified worms could later be visualized by X-ray. Local physicians reported that they sometimes determined the exact position of the living worm by roentgenography with Lipiodol.

14. Trichinosis, which was frequently observed in natives, was not a problem in U.S. troops. Encapsulated larvae usually became calcified and radiologically demonstrable within 6 months after ingestion.

15. Amebiasis, often in the form of amebic dysentery, was one of the commonest diseases in the Middle East and was frequently contracted by U.S. personnel. Parasitic invasion of the intestinal mucosa caused necrosis and ulceration, most often in the cecum, ascending colon, sigmoid, and rectum. In some of the cases observed, the disease took the form of an acute or chronic typhlitis, with only the cecum and ascending colon involved (fig. 280). Amebic granulomas (amebomas), which were observed in all portions of the colon, at times produced partial intestinal obstruction and were misdiagnosed as annular carcinomas. The spastic and irritable cecum and ascending colon often seen in amebiasis were helpful in the differential diagnosis.

16. When the amebic invasion reached the liver, causing amebic hepatitis, hepatomegaly was evident. A further complication was liver abscess, which invariably occurred in the right lobe. A chronic abscess, which was usually large and single, was radiologically evident by elevation of the right diaphragm. Roentgenograms of the chest sometimes showed signs of consolidation of the right lower pulmonary lobe, which led to an erroneous diagnosis of pneumonia.

17. In severe cases of bacillary dysentery, a disease remarkably prevalent in both natives and U.S. personnel, a diphtheritic membrane was often observed in the colon, with necrosis and ulceration. In the chronic variety, in which there was extensive secondary infection by other intestinal bacteria and in which the chronic inflammation periodically became acute, the clinical findings resembled ulcerative colitis, which the indolent ulceration and scarring in the colon also often suggested, pathologically as well as roentgenologically. On fluoroscopic examination, irritability and spasm of the cecum and ascending colon were observed, as well as stasis in the proximal half of the colon.

18. Schistosomiasis was prevalent in Egypt, the Sudan, and Eritrea; the

FIGURE 280.—Amebiasis involving most of right half of colon.

Nile Valley is one of the chief endemic centers of the world. The disease appeared in two forms:

a. In schistosomiasis caused by *Schistosoma haematobium*, the ova, which grew in the wall of urinary bladder, penetrated into the mucosa and muscularis, where they acted as foreign bodies. Clusters of these bodies sometimes became encapsulated by fibrotic tissue, with resultant formation of calcific bodies or of cysts that ruptured into the bladder and left ulcers. The mucosa in these regions proliferated, with occasional formation of polyps that might undergo malignant change. In severe infections, there was total derangement of the mucosa. Large calculi formed, which were demonstrable by X-ray. Less often, the flukes in this variety of schistosomiasis involved the bowel, vagina, and vulva, or passed to the lungs, where they caused small abscesses.

b. In schistosomiasis caused by *S. mansoni*, the snails entered the intestinal wall, where they caused small ulcers and abscesses or mucosal thickening and epithelial hyperplasia. These processes might go on to papillomata, which sometimes underwent malignant change. The pathologic changes were predominantly in the sigmoid and rectum. In this variety of schisto-

somiasis, the ova might also migrate to the liver, where they caused cirrhosis and hepatomegaly. Splenomegaly was also present. At other times, the ova entered the lungs, kidneys, adrenal glands, pancreas, spleen, or myocardium. In such cases, the first manifestation was an inflammatory reaction, followed by encapsulation and calcification readily visible on roentgenograms.

19. The roentgenologic manifestations of yaws were similar to those already described in the Pacific Ocean areas (p. 641). In Equatorial Africa, as in the Pacific, invasion of the skeletal structures caused otitis and periostitis, with resulting bony deformities, particularly the so-called saber shin and dactylitis.

RADIATION THERAPY

Superficial radiation therapy was administered at the 38th General Hospital from January 1943, and at the 113th General Hospital from October 1943, until the end of the war. Superficial therapy was also given briefly in 1943 at the 154th Station Hospital in Iran.

Picker field units were used for all treatments. A Victoreen r-meter had not been provided, but, when one was requisitioned by the 38th General Hospital, it arrived promptly, which was a decided contrast to the experience in the European theater (p. 487). The output checked by this meter was found to be very close to the predicted figures.

Theoretically, therapy given with a field unit was hard on tubes and cables, but there were no such difficulties in these hospitals. It is true that the caseloads were at first very light, but, by 1944, from 15 to 20 patients at a time were undergoing treatment at the 38th General Hospital and almost as many were being treated at the 113th General Hospital. Since most of them were outpatients, who came from varying distances, they arrived at various times during the day; the resulting spacing of treatments further spared the tubes and cables.

The conditions treated, such as chronic dermatoses, fungus infections, acute infections of other types, and various other dermatologic diseases, seldom presented problems. Doses were small and were given at infrequent intervals. Only plantar warts were an exception to the rule of small doses, and they were seldom treated in order to avoid strain on the tubes.

Some conditions treated, such as lymphadenitis and bursitis, could scarcely be classified as superficial. In these conditions, radiation was administered through sharply localized fields, which were barely large enough to include the affected areas.

Radiation therapy was found to be rapidly and extremely effective in the cutaneous variety of leishmaniasis (oriental sore, Aleppo boil), which was frequently observed in Arabia, Iran, and Palestine and was fairly frequent in U.S. troops stationed in these countries. Superficial doses of approximately 75 r were applied to the affected areas, and a total dose larger than 225 r was seldom necessary.

On two occasions, X-ray therapy was given to patients with acute lymphatic leukemia, to control hemorrhagic phenomena. The treatments were emergency measures to permit the patients to be evacuated safely to the Zone of Interior. They were given in the X-Ray Department of the Kasr-El-Aine Hospital in Cairo. This department had a well-trained and cooperative Egyptian radiologist and a modern Westinghouse 200-kvp. unit. This unit was available at any time for deep radiation therapy, but air transportation to the United States was so rapid—about 40 hours—that no sustained deep therapy was indicated overseas.

So far as is known, only one patient with malignant disease was treated in a U.S. hospital in either the Middle East or the Persian Gulf Command. Shortly after the invasion of Italy in September 1943, an Air Force colonel arrived at the 38th General Hospital in Egypt from Naples, to be treated for a basal carcinoma of the cheek that had been discovered on biopsy of the base of an innocent-appearing wart. He was given highly fractionated treatment and returned to Italy. Naturally, no followup was possible.

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Part VII

RADIOLOGY AND THE ATOMIC BOMB

CHAPTER XXXVII

The Role of Radiology in the Development of the Atomic Bomb

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THE BACKGROUND OF THE ATOMIC BOMB

This chapter of the history of radiology in World War II tells the story, in necessarily brief form, of the role of radiology in the development of the atomic bomb that was first detonated at Alamogordo, N. Mex., on 16 July 1945, dropped for military purposes on Hiroshima, Japan, on 6 August 1945, and at Nagasaki 3 days later.

The atomic bomb had been in the making indirectly for at least 15 years and directly for the preceding 3 years. Since it was an entirely new development, a certain amount of background information is necessary to make clear the relation between its military aspects and its medical aspects, which were practically entirely radiologic. Therapy did not enter the picture in the Zone of Interior because there were no radiation casualties.

Even when it was militarily over Japan in August 1945, each bomb was still a scientific device, an experimental model, and the first of its kind. Before these bombs could be dropped, a new agency had to be created, the Manhattan District of the Corps of Engineers. The uranium oxide required for the manufacture of the bombs came from several sources, about a seventh of it from the network of mines in Colorado that had been actively developed early in the war to supply the large demand for vanadium in war industry. The uranium oxide for the Manhattan Project came not from further mining operations but from refining the large stockpiles of vanadium tailings at these mines. Ores were imported also from Canada and the Congo. Ore-refining and metallurgical plants were set up all over the United States. Finally, new techniques had to be developed for the fabrication and delivery of uranium 238, the metal used in making material for atomic bombs.

Many other scarce materials were required for the production process and the chain-reacting piles. The procurement of these materials would have been impossible without the high priorities assigned by the War Department for all the operations of the MED (Manhattan Engineer District).

Probably close to a million civilians were engaged, directly or indirectly, in this gigantic effort during the final 6 months of the war.

There were three so-called secret cities (sites) involved in the production of the bomb and the materials for it:

1. Oak Ridge, Tenn., which in 1945 had a resident population of more than 70,000. It was responsible for the isotopic separation of U–235 from U–238, which could be accomplished readily by three different methods (p. 854).

2. Hanford and Richland, Wash., on the Columbia River. Here, plutonium Pu-239), another bomb material, was manufactured from U–238 in chain-reacting piles.

3. Los Alamos, N. Mex., situated on the top of an almost inaccessible mesa. Here was located the scientific-engineering laboratory for both the design and the fabrication of the bombs.

The first bomb was tested on 16 July 1945, on a high tower—which disintegrated during the detonation—at Alamogordo (p. 884). This site was part of an Air Force bombing range in the desert—Jornada del Muerto—south of Carthage.

Among the university and federal laboratories engaged in extensive secret isotope separation projects were:

1. The Columbia University Laboratory, N.Y. (under Harold C. Urey, Ph. D.), known as the SAM (Special Alloyed Materials) Laboratory.

2. The University of California Radiation Laboratories (under Ernest O. Lawrence, Ph. D.).

3. The Special Research Division, the Naval Research Laboratory (under Philip H. Abelson, Ph. D.).

4. The National Bureau of Standards (under Lyman J. Briggs, Ph. D.).

5. The University of Chicago Metallurgical Laboratory, generally known as the Met Lab (under Arthur H. Compton, Ph. D.).

Manufacturing plants that participated in the project were numbered in the hundreds and were distributed all over the country.

Every step of these research and manufacturing processes in which uranium or plutonium was used was fraught with radiation hazards. Some of these hazards were—or could have been—of fantastic magnitude, such as those from the pile ashes produced during the chemical extraction of plutonium from neutron-bombarded U–238. Every step in the procurement of U–238 from mining to metal fabrication was accompanied by the constant production of the unwanted and dangerous daughter-products, uranium X1 and uranium X2, which are strong beta-radiation emitters.

Radiologists had had a wide experience with high voltage X-rays and with radium or radon, as well as a more limited recent experience with radioactive isotopes. They were familiar with tissue reactions from radiation and with the lethal effects and absorption dangers from X-rays, gamma and beta rays, alpha particles, and neutrons. They also possessed electroscopes, roentgen meters, and ion chambers, all new and all at once in great demand. It

was natural, therefore, that radiologists should constitute the initial personnel concerned with the protection of the workers in this vast organization.

RADIATION THERAPY

The principal approach of radiology to the atomic bomb was by way of the effects of radiation therapy, supplemented by the first laboratory experiments with radioactive isotopes. In the interim between the World Wars, radiation therapy was an empirical specialty rather than one based on precise fundamental knowledge. Its motivation was a frantic search, against hopeless odds, for a cure for cancer. The clinical diagnosis of cancer was still discouragingly inexact, and all too often the radiologist first saw the patient when his disease was already far advanced and already in the metastatic stage. Treatment therefore was usually little more than a temporizing procedure, intended only to relieve pain and reduce the bulk of the growth.

Although the radiotherapist was generally limited in both approach and facilities, some progress had been made before 1940 by courageous and imaginative workers in tracer technology (p. 835) and allied fields, who took advantage of the availability of radioactive isotopes in large quantities. Perhaps the first large-scale, well-organized therapeutic assault on malignant disease was on chronic leukemia and polycythemia by Dr. John H. Lawrence, at the University of California School of Medicine on the San Francisco campus, who used phosphorus 32 secured from the cyclotron developed by his brother, Dr. E. O. Lawrence, on the Berkeley Campus (*1*, *2*). Dr. J. H. Lawrence's work was shortly verified at the Harvard University Medical School, Boston, Mass., by Dr. Shields Warren, who used similar material supplied by the Massachusetts Institute of Technology, Cambridge (*3*). In spite of the hopeful results obtained by both Dr. J. H. Lawrence and Dr. Shields Warren, clinical hematologists remained skeptical, and the controversy raged for years before the usefulness of radioactive isotopes in malignant disease was generally accepted.

STATUS OF PREWAR RADIOLOGIC RESEARCH

Research in radiology in the medical schools of the United States in the late 1930's was granted to be of some—though limited—value. It developed teachers. It provided a field of work for graduate students. It helped to train hospital residents, and there was considerable discussion about making some research work a minor requirement for certification in radiology. But research in radiology had little official recognition in the allocation of funds or the provision of space and facilities for it. Few research groups were adequately financed, efficiently organized, and properly equipped for basic experimental work in this field. Grants were small and were seldom given for more than a year. The investigator frequently had to build his own equipment, operate it in a basement or in some unfinished space in hospital or

school, and use hospital radiation sources at night or on weekends. A machinist or a physicist was seldom available for more than part time, if that, and a grant that provided for a technician or two was a major production.

The system described was not productive of scholars or of significant research results. By its very nature it restricted research to small Arbeits that could be finished within a limited period of time (seldom more than a year) and that involved small numbers of small animals.

The results of this kind of research were seldom accepted until they had been repeated and verified by other observers, a criterion that often took several years. There was every reason why they should not be accepted offhand. The experiments were seldom well controlled. Not enough animals were used to be statistically significant. The variations normally present in small series of stock animals, particularly animals obtained from pounds, also altered results. Paucity of personnel and equipment and lack of continuity prevented any long-term studies of healing or degeneration after irradiation, though the need for specific information on these phenomena was apparent almost daily in cancer clinics. Growth and fertility cycles of larger animals were too long to fit into such an erratic pattern, and acute, short-term experiments had to be devised. The number of fruitful investigations of this type was limited, and many potential research workers lost interest.

The situation just described is not an exaggeration. It was characteristic of research and advanced training in radiology up to the outbreak of World War II. It was not until 1942, when data were urgently needed in the development of the atomic bomb, that funds for research and engineering became available in larger and significant amounts.

The cyclotron was first developed at the University of California in Berkeley in 1930 by Dr. E. O. Lawrence and his associates, and, as would be expected, some of the most active prewar experimentation and training were conducted there. The physiologic significance of these developments and of the associated development of instruments and techniques was soon recognized elsewhere, and active work along these lines began to be conducted in other universities. The clinical use of phosphorus 32 at the University of California by Dr. J. H. Lawrence has already been mentioned. In the Department of Radiology at the same school, Dr. Robert S. Stone and his group undertook therapeutic trials of high energy particles (neutrons from the Sloan generator) in cancer.

On both the Berkeley and the San Francisco campuses of the University of California young graduate students and young physicians were trained in these new techniques. By this fortunate circumstance, some of the men who played an outstanding role in the development of the atomic bomb were ready for assignment when the need arose to safeguard the health of the increasing numbers of participants in the University of Chicago Metallurgical Laboratory and the secret sites in which materials for the bomb were developed. Many well-trained young physicians were also produced at the University of Rochester, Rochester, N.Y. (p. 845), and later at the University of Chicago.

TRACER STUDIES

The advent of radioactive isotopes in the early 1930's promptly corrected the discouraging research situation just described and opened the way for an almost unlimited number of short, cheap, highly productive experiments that could be completed within a budget year. As a result, the end of this decade and the beginning of the 1940's saw a recrudescence of interest in radiation experiments, at a most propitious time for the development of the atomic bomb. The era of intensive study of dynamic metabolic and physiologic activity was now indeed at hand.

Tracer studies with stable isotopes were expensive, and most investigators also found them too difficult to be practical. These isotopes were therefore not widely used until after the war. Unstable radioactive isotopes, however, had many convenient attributes. Phosphorus 32, for instance, which was usually used as sodium phosphate, could be readily produced in the cyclotron by direct bombardment of the element, and no subsequent chemical steps were necessary to remove the stable phosphorus carrier; this step was necessary in many other radioactive isotopes. Phosphorus 32 was nontoxic and highly soluble. Its beta radiation was easily measured by available Geiger counters. It could be safely handled and easily shipped by mail, since its beta radioactivity was weak enough to be protected against by a standard laboratory brown bottle. When it was given intravenously or parenterally, it diffused widely in the body fluids and was readily excreted. Its relatively short half-life (14 days) and its high rate of excretion were attractive features in metabolic and physiologic experiments as well as in its clinical applications.

Because of its high chemical activity and its widespread presence in most body constituents, the use of P–32 as a radioactive tracer opened exciting pathways for study in almost every field of biology and medicine. The conventional chemistry of phosphorus and its salts is so complex that up to this time relatively little had been learned concerning its function in energy exchange. Now for the first time there was open to relatively easy investigation its role in the appetite minerals of bones and teeth, in which it participates in the binding of calcium, lead, radium, strontium and other metals, as well as its role in brain tissues and in the tissues of many other organs.

When isotopes once became available and their importance was recognized, there was almost as much interest in the application of tracer techniques as there was in the development of the atom itself. In fact, supplying radioactive isotopes for biologic investigation consumed so much time in the laboratories that owned cyclotrons that it often interfered with the experimental work underway in physics.

The first work with cyclotrons was done at the Massachusetts Institute of Technology and at the University of California. Considerable work along these lines was also done at the University of Rochester. Late in 1941, the University of Rochester obtained a million-volt X-ray generator (fig. 281) for industrial purposes, to make radiographs of armored vehicles such as

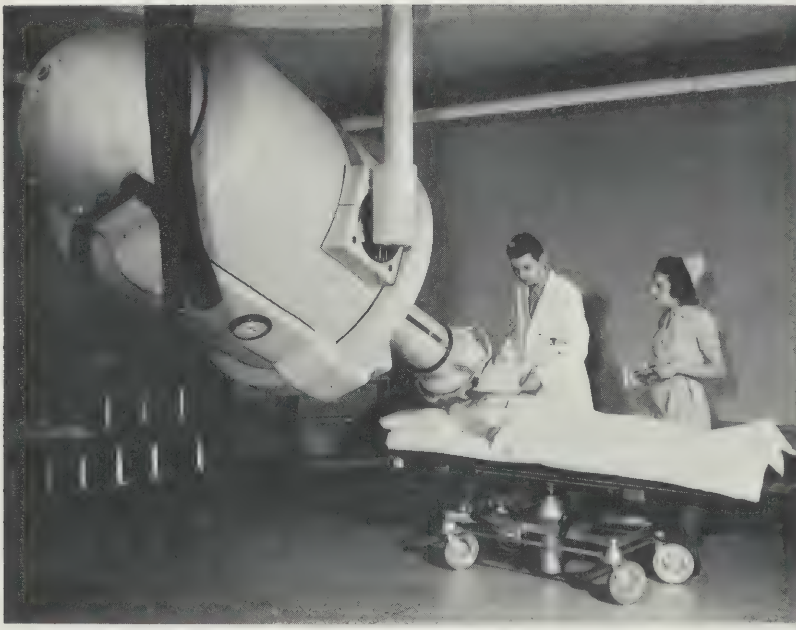

FIGURE 281.—Typical million-volt X-ray machine used early in World War II.

tanks. This work was soon finished and the machine became available for biologic research.

By this time, a considerable amount of work had already been done in the Rochester Medical laboratory, which was under the direction of Dr. Stafford L. Warren. William F. Bale, Ph. D., developed the dipping finger Geiger counter for wet ash techniques and thus made it possible to use the radioactive isotopes made by the local group of physicists (Lee A. DuBridge, Ph. D., Sidney W. Barnes, Ph. D., and Victor Weisskopf, Ph. D., among others), as well as the isotopes obtained from Robley D. Evans, Ph. D., at the Massachusetts Institute of Technology.

Also at the University of Rochester, a number of workers became interested in metabolic tissue effects of radiation and in its genetic effects. These workers included Harold C. Hodge, Ph. D., Don C. Charles, Ph. D., Curt Stern, Ph. D., Luville T. Steadman, Ph. D., and Dr. Andrew H. Dowdy.

GROWTH OF LITERATURE

One final outgrowth of these nationwide research activities played its part in the development of the atomic bomb: Interest in tracer studies led to the rapid growth of several professional journals in this specialized field, including *Radiology*, the *American Journal* of *Roentgenology*, the *British Journal* of *Radiology*, *Acta Radiologica*, and *Strahlentherapie*. The litera-

ture of what is now known as radiobiology accumulated rapidly, and frequent collective reviews were published. By 1942, a rather large and comprehensive literature existed, from which could be derived many of the safety policies and principles of operation and protection later put into effect at the University of Chicago Metallurgical Laboratory and elsewhere by the contractors and the Medical Section of the Manhattan Engineer District. Many, of course, had to be devised de novo.

FIRST STAGES IN THE DEVELOPMENT OF THE ATOMIC BOMB

The Uranium Program

At the Conference on Theoretical Physics held in Washington, D.C., 26 January 1939, which was attended by most of the principal workers in this field, reports were made on the work done on the fission of uranium by Otto Hahn, Ph. D., Fritz Strassmann, Ph. D., Otto R. Frisch, D. Ph., and Lise Meitner, Ph. D. Their work was confirmed by telephone during the conference by Niels H. D. Bohr, Ph. D., from his laboratory in Copenhagen, Denmark. Shortly afterward, his observations were also confirmed by workers at Columbia University, The Johns Hopkins University, Baltimore, Md., the University of California, and the Carnegie Institution of Washington, D.C.

By June 1940, 18 months later, the principal facts about fission of the atom had been discovered and were known to the scientific world. A chain reaction had not yet been obtained, but the theoretical possibility, at least, had been demonstrated, and several routes that might lead to it had been suggested.[1]

Meantime, because of their military implications, these developments had

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[1] "Actually, it was in March 1939 that Joliot, Hans Halban, and Lew Kowarski, in the College of France, demonstrated that rupture of a uranium nucleus produced by one neutron is accompanied, in addition to the formation of two fission products and corresponding energy liberation, with the emission of several neutrons called secondary neutrons.

"Actually, experience showed that the secondary neutrons which are emitted at very high velocity become, when they are slowed down, more apt to provoke fission of uranium–235. But the method of slowing down rapid neutrons was known. It is sufficient to place about them substances containing light nuclei in contact with which they give up, by successive shocks, a part of their energy in the same manner that a billiard ball s slowed down when it hits against billiard balls of the same size to which it gives up, little by little, its actual force. Consequently, one is thus led to mix with uranium a material called a moderator which slows down the neutrons without absorbing them too strongly. This principle constitutes the basis for the first patent request deposited in France in the beginning of the month of May, 1939. One of these is devoted to the utilization of explosive power of uranium, the others pertain to machines generating energy on the basis of uranium, which were later named piles, or atomic reactors. These patents, the first to have been deposited in the world, have been recognized by many countries.

"The problem of slowing down agents began with hydrogen but the study of mixture of ordinary water and uranium rapidly showed that hydrogen absorbed the neutrons too rapidly to be of value. Finally, the Joliot group arrived at the conclusion that two moderators or slowing down materials could, without a doubt, be utilized in a practical fashion—pure carbon in the form of graphite and heavy water." Extracts from L'Aventure Atomique by Bertrand Goldschmidt, pp. 24 and 27.

been brought to the attention of President Franklin D. Roosevelt, in the fall of 1939, largely on the insistence of Dr. Albert Einstein. An Advisory Committee on Uranium had been appointed as a subcommittee of the NDRC (National Defense Research Council), to review the progress of the research and to keep the President and the Council advised.

The structural changes undergone by the Advisory Committee on Uranium (known as S–1 Section, NDRC) (*4*) are not essential to the story of the relation of radiology to the atomic bomb. When they were completed, late in November 1941, the S–1 Section had been placed under the OSRD (Office of Scientific Research and Development), directly under Vannevar Bush, Sc. D., its Director, and had no further connection with the National Defense Research Council. In its new position, the S–1 Section was administered by James B. Conant, Ph. D., representing Dr. Bush, and Dr. Briggs was its Chairman. With this change, the section became a full-scale operating agency.

The element of secrecy had entered the picture well over a year before, when it became known that the British and German governments were both interested in the possibilities of uranium fission for military purposes. It was for this reason that the Advisory Committee on Uranium became known simply as the Section 1 Committee.

After 1939, by the voluntary, self-imposed action of U.S. and British physicists, there was an almost complete cessation of published articles in the field of atomic fission. In the middle of 1940, the NRC (National Research Council) organized a Reference Committee, with several subcommittees, to control the publication of such articles in every field of possible military interest. Papers were forwarded by the editors of scientific and professional journals for review by the committee, which advised against publication if there was any possible military information of significance in them. This was a highly important and very successful action, for by this time little work in the field of atomic fission was being done that was not already incorporated in the OSRD program and therefore under its supervision.

By June 1940, it was known that fission was produced by thermal neutrons in U–235, the rare isotope of uranium. It was not yet known that it was also produced in U–238, the more common isotope. Six months later, active work in the field of fission was underway in 10 or more universities, as well as at the Carnegie Institution of Washington, the Standard Oil Development Co., and the National Bureau of Standards.

The year 1941 was highly critical. Results from various investigations confirmed more surely the important military implications of uranium fission, the work on which was expanded at a very rapid rate. At the request of Dr. Bush and Dr. Conant, several special reports were made by the National Academy of Sciences. When British scientists reported that a U–235 bomb of great power was feasible, Dr. Urey and George B. Pegram, Ph. D., from Columbia University were sent to England for firsthand discussions.

On the recommendation of OSRD, the President agreed to broaden the program, to set up a different organization, to provide funds for the expanded

program from a special source, and to effect complete interchange of information with the British.

The "different" organization set up was a Top Policy Group, consisting of the President, the Vice President, the Secretary of War, the Army Chief of Staff, and Drs. Conant and Bush (*4*).

By December 1941, the largest research and pilot projects in the uranium program were concentrated in three universities, Columbia, under Dr. Urey; Chicago, under Dr. Compton; and California, under Dr. E. O. Lawrence. On the 16th day of that month, it was agreed at a meeting of the Top Policy Group that the OSRD should press on as fast as possible with the development of the fundamental physics of atomic fission and with the engineering, planning, and, particularly, the construction, of pilot plants. Later it was also agreed that the Army should take over the whole program as soon as full-scale construction was started. This stage was reached on 18 June 1942.

When all S–1 Section activities were reviewed in April and again in May 1942, various methods of producing material for the atomic bomb were discussed. It was the decision of the Section 1 Committee that, since there was no certainty of success with any single large-scale method, no chances should be taken and all feasible methods of producing fissionable material should be explored (*4*).

During this period of development, the committee was perpetually faced with two anxieties: 1. Would the atomic bomb be a decisive weapon? 2. How much were the Germans doing in this field? In the satisfactory answers to these questions lay the justification for the withdrawal for the development of the bomb of highly critical materials and always short manpower from the remainder of the national military effort.

Establishment of the Manhattan Engineer District

In May 1942, OSRD S–1 Section was terminated and was replaced by a smaller OSRD S–1 Executive Committee, with Dr. Conant as Chairman (*4*). While Dr. Bush alone had the authority to establish OSRD policies and commit OSRD funds, he ordinarily followed the recommendations of this committee.

In a report prepared by the S–1 Executive Committee in June 1942, it was stated that kilogram amounts of either U–235 or plutonium (Pu–239) would be very highly explosive and would be equivalent to several thousand tons of TNT; that the detonation time could be controlled; that it would take large production facilities to produce the necessary fissionable material to make such a bomb; that the bomb materials could be produced by at least four methods (three using U–235 and the other Pu–239); that all four methods should be employed because the urgency of the situation made it unsafe to rely on any single method; and, finally, that with adequate funds and priorities, the project could probably be completed in time to be of military

FIGURE 282.—Maj. Gen. Leslie R. Groves, Commanding General, Manhattan Project.

value in the war then in progress. The project, however, would be a drain on, and would interfere with, other war activities.

The report just summarized was sent by Drs. Bush and Conant to Vice President Henry A. Wallace, Secretary of War Henry L. Stimson, and Army Chief of Staff Gen. (later General of the Army) George C. Marshall on 13 June 1942 (*4*). All approved it. On 17 June 1942, it was sent by Dr. Bush to the President, who initialed it. A copy of the report was then sent by Dr. Bush on 19 June 1942 to Brig. Gen. (later Lt. Gen.) Wilhelm D. Styer, GSC, Lt. Gen. Brehon B. Somervell's Chief of Staff.

The day before, Col. (later Brig. Gen.) James C. Marshall, CE, was instructed by the Chief of the Corps of Engineers to form a new district in the Corps to carry on special work assigned to it (*4*). This district, designated the Manhattan Engineer District, was officially established on 13 August 1942. The special work assigned to it, the development of the atomic bomb, was labeled, for security reasons, the DSM (Development of Substitute Materials) Project (*4*).

On 17 September 1942, Secretary of War Stimson assigned Brig. Gen. (later Lt. Gen.) Leslie R. Groves (fig. 282) to be in complete charge of all Army activities of the DSM Project (*4*). General Groves thus became commanding general of what was soon called the Manhattan Project, and which was the planning headquarters of the entire program. The Manhattan Engineer District was its major operating arm.

General Groves was specifically directed by the President to take all

means to insure the security and secrecy of this project. Since the OSRD report of 13 June had been approved by the President, General Groves, on that basis, asked for, and received, the highest priorities for procurement of material. Without those priorities the program could not possibly have succeeded.

The research and development contracts of the OSRD were formally turned over to the Manhattan Engineer District on 1 May 1943 (*4*).

ESTABLISHMENT OF THE MEDICAL SECTION MANHATTAN ENGINEER DISTRICT

During the fall and winter of 1942–43, it became evident that the Manhattan Engineer District must develop an extensive and detailed medical safety program for its uranium pilot and production programs, which were now beginning to be spread all over the country, but particularly for the secret cities (p. 832). The Clinton Engineer Works was being organized to develop the 58,800-acre site at Oak Ridge, Tenn., whose purchase had been authorized in September 1942. At Hanford and Richland, a site had been selected for the operation of the Hanford Engineer Works, and construction on its 420,000 acres would begin in April 1943.

Withdrawing medical personnel assigned to the University of Chicago Metallurgical Laboratory (p. 864) for tours of duty in the Manhattan District Office was clearly no answer, and in March 1943, under conditions of strictest secrecy (p. 846), Dr. Stafford L. Warren, Professor of Radiology at the University of Rochester School of Medicine, was engaged to advise the District Engineer on "special materials."

Dr. Warren's first consultation in the New York office of the Manhattan Project with Maj. (later Lt. Col.) Hymer L. Friedell, MC, who had been assigned to the new Manhattan Engineer District (p. 839), was very general. Major Friedell, who displayed a knowledge of the new field of isotopes not common in most recent residents in radiology, questioned Dr. Warren, without giving him any reasons, concerning shielding against radiation, protection against radioactive dusts, safe standards of exposure, and similar matters. Dr. Warren replied that there were no experimental data upon which answers to most of these questions could be based. Major Friedell inquired whether some of the experiments necessary to provide the answers could be carried out at the University of Rochester, in secret, if laboratory facilities and funds were provided. Would Dr. Warren produce an outline for certain specific experiments within the next 2 weeks? As soon as his proposals could be examined and it could be determined that they would meet the needs of the project for which they were designed, a contracting officer from the Manhattan District would be sent to the school to authorize construction, which would be begun as soon as possible.

In the meantime, Major Friedell continued, a hospital was being planned,

FIGURE 283.—Lt. Col. (later Maj. Gen.) Kenneth D. Nichols, CE, at Oak Ridge Headquarters for the Manhattan Engineer District. During working hours the desk was piled high with reports, all highly classified; it was stripped for this picture, as it was every night. There were severe penalties if any papers were left out or if desks or safes were left unlocked, even in the most closely guarded areas.

and decisions must be reached concerning its location and its size. If Dr. Warren would be willing to spend 3 days the following week looking over the site that had been tentatively selected for it, Major Friedell would fill him in on "some things." Lt. Col. (later Maj. Gen.) Kenneth D. Nichols, CE (fig. 283), Chief Operating Officer for the Manhattan Project under General Groves, who came into the office about this time, said that the trip would impress Dr. Warren with the importance of the project and would convince him of the necessity of staying with it, even though its specific nature could not yet be disclosed to him.

The inspection of the hospital site at Oak Ridge duly took place (p. 872), and by the end of May 1943, most of the information about the uranium program had been disclosed to Dr. Warren. He accompanied Major Friedell on inspection trips to plants in New York City, Buffalo, and Niagara Falls, in which uranium ore concentrates were being refined in large quantities and in which there were two problems, the toxicity of uranium salts and the radiation hazards in the discard (p. 854).

By 1 August 1943, the medical activities of the Manhattan Engineer District had become so unwieldy that it was necessary to define them more

clearly. On 10 August 1943, Colonel Nichols, then deputy District engineer, created the Medical Section, MED, with Major Friedell as executive officer and Dr. Warren as civilian consultant to him. Capt. (later Maj.) John L. Ferry, MC, was also assigned to the Medical Section.

In October 1943, Dr. Warren reported to General Groves that the organization of the Medical Section, MED, was essentially complete and that he could no longer function effectively in a civilian status. On 3 November 1943, he was commissioned Colonel, MC, AUS, and was appointed Chief of the Medical Section, MED, and medical advisor to the commanding general, Manhattan Project.

Later in November 1943, the office of the Medical Section, MED, was moved to Oak Ridge, where it was operated under Colonel Nichols, then District Engineer. The Medical Section functioned here until the end of the war, with Colonel Warren as Chief, Major Friedell as deputy chief, and Capt. (later Maj.) Robert J. Buettner, MAC, as administrative officer.

Mission.—The mission of the Medical Section, MED, outlined by Colonel Nichols when it was created, covered the following functions:

1. The conduct of, arrangement of, supervision of, or liaison with, such research work as is considered necessary for carrying out the functions of the Medical Section.

2. The determination of health hazards and the institution of protective measures against them in all operations of the Manhattan District.

3. The instruction of contractors and area engineers concerning the necessity of safeguarding the health of their personnel and making proper use of hospitals and related services.

4. Assistance to, cooperation with, and periodic inspections of, the area engineers' and contractors' programs, to be certain that the protective practices directed were being carried out.

The order outlining these functions of the Medical Section, which was deliberately vague for security reasons, was distributed to area engineers in charge of contractors, whose operations now covered most of the northern and western parts of the United States.[2]

The mission of the Medical Section, Manhattan Engineer District, thus concerned three main responsibilities:

1. The coordination of the biomedical research programs in the universities. This was one of the most important functions of the Medical Section. The rapid development of new information made it imperative that channels of communication be developed among radiologists, physicists, engineers, contractors, and university research groups. The Medical Section helped to disseminate this information and thus expedited the development of the safety programs that were introduced in the various stages of the production program.

2. The industrial safety procedures required for individual on-site and

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[2] The document referred to remained classified when this volume was ready to be published, and its title, therefore, may not be given here.—A. L. A.

off-site contractors in various locations, and the inspection program that insured their observance.

3. The medical care and public health protection of populations at the secret sites.

Procurement of supplies for hospitals and for the medical programs, both on-site and off-site, was never a problem, since it was covered by the Manhattan Engineer District priority, about which no questions were ever asked.

PERSONNEL AND TRAINING

Prewar Training

It was extremely fortunate that training in radiology underwent a considerable expansion just in time for the young men who were to play an essential part in the later development of the atomic bomb to take advantage of it. In most teaching institutions the residency in radiology had been lengthened to 3 years, and in a few to 4 years. Also a year of research was being discussed as a residency requirement (p. 832) and was attracting an occasional graduate student.

It is difficult to realize today (1965, some 25 years later) how little knowledge about radiation was available in 1940 and how important these few well-trained pioneers were to the successful production of the atomic bomb over the 4-year period in which frightening amounts of radioactive material were handled in absolute safety. In 1940, a curie (1 gm.) of radium was considered a dangerous amount and few institutions owned as much. A few years later, the megacurie, equivalent to 1,000 kg. of radium, was to become commonplace.

The development of the Lawrence cyclotron at the University of California in Berkeley, and the excitement created in the biologic world by the many possibilities opened by the availability of radioactive isotopes, brought not only young physicians but also physicists, biologists, and biochemists into the field of radiology.

By the late 1930's, the need for physicists as permanent, full-time members of cancer therapy teams had become indisputable. The evolution was gradual. Not infrequently the physicist first entered the picture when he prepared radon seeds from radium salts, a technique by then employed in many large hospitals. When a new high energy X-ray source was installed in an institution, the physicist was needed to keep the equipment in operating condition for the radiologist, who soon came to feel the need for the help the physicist could give him.

A less frequent sequence began in reverse, with the exploration of high energies in a department of physics, with the gradual involvement of the radiologist in the project. Which method of association occurred makes no difference now. What is important is to realize that for perhaps a decade before the United States entered the war, a gradual synthesis of physics and

biology, which was both exciting and productive, was developing. The result was the evolution of a new field of science, biophysics, and the widened education of young scientists who matured out of their Ph. D. courses and of young physicians who completed their residencies in radiology and medicine just in time to be incorporated in the program of the Medical Section, Manhattan Engineer District.

At the University of California during the 1930's, many graduate and postdoctoral fellows worked on radioactive emitters on the Berkeley campus. In the Medical School of the University, on the San Francisco campus, the work of Dr. J. H. Lawrence has already been mentioned. Dr. Friedell was trained in Dr. Stone's Department of Radiology there. Another worker in the program was Dr. Joseph G. Hamilton, an imaginative and brilliant neurologist, who had an avid interest in experimentation. His association with the Stone group proved ideal for them as well as for him. At this time, Dr. Stone was deeply concerned with the hazards, measurements, dosages, and effects of X-rays and neutrons in his work with the new Sloan generator. Dr. J. G. Hamilton, in return for obtaining isotopes from the Lawrence cyclotron for his own work, took on the supervision of the medical health and safety of the physicists, engineers, chemists, physicians, and technicians working in the rapidly expanding group on the Berkeley campus. He set the guidelines and the exposure standards and instituted the protective measures against the neutrons and other radiation emitted by the cyclotron as well as against the radioactive emitters produced on the cyclotron target. He also participated in the development of safe handling practices for the new radiochemical ("hot") extraction purification procedures. He devised micromethods and other procedures for biologic testing of new radioactive elements as tracers. His exploitation of radioactive isotopes and their biologic and biochemical properties was highly imaginative and even spectacular (*5*). He was an excellent teacher, and by the middle of the 1930's he had begun to attract to the University a number of good graduate students, postdoctoral fellows, and technicians who later participated in the atomic bomb program, among them Kenneth G. Scott, Ph. D., and Cornelius A. Tobias, Ph. D.

Many well-trained young physicists were also produced at the University of Chicago by the Compton group. These men (among them, David Rose, D. Sc., Herbert M. Parker, Ph. D., and Ernest O. Wollan, Ph. D.) devised most of the instruments necessary for both the small and the large quantities of radiation of all sorts used in the biologic and safety work of the whole program.

Similarly well-trained men were available at the University of Rochester. In 1943, when the high-voltage generator unit was converted and expanded for use in the intensive program of biologic research then under way, the program could be begun at once on tolerance doses of X-ray (Dr. Dowdy); on genetics and tissue effects of radiation (Dr. Stern and Dr. Charles); on toxicology and standards of safety for noxious chemical substances (Dr. Hodge); and on instruments (Dr. Bale).

Procurement of Medical Personnel

The procurement of suitable personnel for the Medical Section, MED, constituted a serious problem, though it was less serious than it might have been: Fortunately, both the civilians and the medical officers who first became concerned with health and safety matters were unrestricted in their point of view. They promptly recognized the broad implications of large-scale uranium operations in almost every field of medicine, and they had both the intelligence and the courage to anticipate the needs of the almost incredible expansion of the program soon to occur.[3]

Since the medicobiologic program of the Manhattan District was a late (1943) development in the general organization for the war effort, it was feared in many scientific circles that the organization of an expanded research program in radiation and radioactivity, both new fields, would be almost impossible because of lack of manpower. This fear proved groundless, for several reasons:

1. Many competent men, especially among younger physicians and scientists, had not yet been recruited for service because their dedication to their work in cancer, metabolism, and similar fields was so great that their skills did not seem particularly useful in the war effort.

2. The accelerated educational program in the medical schools was still not fully underway in 1943, and the schools had not yet been as completely stripped of their faculties by Selective Service calls as they were in 1944 and 1945.

3. A small but hard core of experienced personnel was available, as just pointed out, because of the fortunate interest that had developed in tracer experiments and similar studies just before the war.

The professional radiologists who first entered the Medical Section of the Manhattan Engineer District were recruited chiefly from the field of cancer therapy, in which they had been interested in high energy radiation, rather than from the diagnostic radiology group. They included Dr. Simeon T. Cantril, Dr. Dowdy, Dr. Friedell, Dr. Stone, and Dr. Stafford L. Warren. Others were specialists in internal medicine (Dr. J. H. Lawrence, Dr. John B. Hamilton, Dr. Leon O. Jacobson, and Dr. Louis H. Hempelmann). Still others were from the basic biologic sciences (Kenneth S. Cole, Ph. D., Karl Z. Morgan, Ph. D., Dr. Parker, Dr. Bale, Dr. Hodge, and Dr. Scott). No matter what their previous specialty, all were interested in using radiation or isotopes as tools to explore basic mechanisms in biologic systems. As the project became more complex, experts from other fields of medicine were brought in, and eventually radiologists constituted only a relatively small portion of the personnel.

Medical Corps officers.—Medical Corps officers were used as far as possible in the secret sites at Oak Ridge, Hanford, and Los Alamos, for two

[3] See footnote 2, p. 843.

reasons. The first was that it was impossible to find civilian physicians with the required quality of training in large enough numbers to staff the hospitals and clinics at these sites. The second reason was that medical (military) officers were more desirable, for security reasons, in locations in which accidents with radiation exposure might occur.

In September 1943, therefore, an arrangement was worked out by correspondence between the District engineer, Clinton Engineer Works, Oak Ridge and The Surgeon General, to "commission or provide commissioned officers and funds" for the medical and dental care of military personnel wherever facilities for such care were available. Medical, dental, veterinary, and administrative officers would be supplied as requested (as well as medical supplies) for the military detachments assigned to the Manhattan District, without disclosure of their destination or mission. Efficiency reports would be retained by the Manhattan District. For security reasons, no transfers would be made into or out of the District without the approval of the District engineer.

Col. Arthur B. Welsh, MC, was appointed by The Surgeon General to provide liaison between his office and the Manhattan District. In 1945, Colonel Welsh was replaced by Lt. Col. Carl C. Sox, MC. Major Friedell, representing the Medical Section, MED, conferred with Colonel Welsh on the procurement of personnel as the need arose. On the advice of Maj. Charles E. Rea, MC (p. 873), as many officers as possible who were to serve in a given site were secured from the same medical school residency programs, so that they would already know each other and would be used to working together. The policy was very effective, one reason being that since the families were already acquainted with each other, there was less loneliness and a better esprit de corps is these isolated assignments.

On-the-job training expedited the production of special investigators, supervisors, and monitors, as well as the special workers who were in charge of the complex protective techniques considered necessary for safety.

SECURITY

As soon as the Manhattan Engineer District began to operate on a large scale, it became apparent that safety practices were a primary requirement, quite apart from humane considerations, for two reasons, both of which arose from the necessity of maintaining absolute secrecy:

1. If scientists or workers in any part of the project should receive enough radiation, or should absorb enough radioactive material, to produce physiologic damage, with subsequent clinical manifestations, or should die from the effects of the damage, it would be impossible either to keep the project secret or to procure enough employees to carry on with it.

2. If controls over radioactive materials in effluent air and water and on contaminated clothing were not strict, radioactivity might become measureable in the surrounding community and the knowledge might leak out that a

secret government project was operating on a large scale with radioactive materials.

Security was therefore, both directly and indirectly, the original driving force that made the most hazardous, and probably the single largest, industry under one control in World War II the safest of all wartime enterprises.

The assignment of special research projects in the program to a number of different laboratories, in accordance with their special capacities and past experience, made it possible to restrict and divide the whole program into compartments without disclosing its goal and without the integration of any special research projects with the whole project. This principle was so strictly followed that each participant in the program knew only enough to carry out his own assignment. The actual names of critical materials were never used. The code names or numbers for them used by a local contractor or research group might be known only to the area engineer, and he, in turn, might use for the same materials a different code, known only to the District engineer.

The pace and pressure were usually so great that there was little time for speculation, and the general attitude of the medicobiologic research workers was "If this is all we need to know, we don't want the responsibility of knowing any more."

The length to which security measures were carried is evident in the method used when Dr. Warren was first invited to discuss becoming civilian consultant "on special materials" to the Manhattan Engineer District. In the middle of February 1943, he was invited by Albert K. Chapman, Ph. D., vice president and general manager of Eastman Kodak Co., Rochester, N.Y., to have lunch with him, General Groves, and Colonel Marshall at the Rochester Club. During luncheon, Dr. Warren was asked by Dr. Chapman to describe some of his work with radiation and isotopes, and, particularly, to describe the million-volt X-ray equipment for X-raying Army tank castings (p. 835). Eastman Kodak Co. was involved in this work. The two officers expressed themselves as particularly interested in the shielding of this apparatus.

After lunch, Dr. Chapman took his departure, after first advising Dr. Warren to agree to do whatever the officers asked of him. The officers then took Dr. Warren to a private room, where one of them closed and locked the door and closed the transom while the other looked into the closet. Both of them then looked out of the closed window, and, when they sat down, there was a moment of quiet, during which they seemed to be listening.

After these preparations, General Groves asked Dr. Warren if he would consider working on a very important medical program for the Government. Dr. Warren replied that he was already committed to the hilt with teaching, OSRD work, and the tank castings program he had described at lunch. He was asked if he could take on more important research in his own field at the University if he were provided with research funds in adequate amounts and a laboratory building, and if a replacement could be found for him in his OSRD work. He would also be needed on occasional trips to look over certain

research and other programs. Would he be willing to become a consultant for a trial period of several months? It was exceedingly important that he should, but the work was so confidential that nothing could be explained to him until he had accepted the offer.

Dr. Warren was given a number to call in New York, to arrange for a trip there to talk over the matter with another officer (Major Friedell) already on the staff of the project. He was told to talk to no one about the meeting with General Groves and Colonel Marshall except Dr. Alan Valentine, President of the University of Rochester, Dr. George H. Whipple, Dean of the Medical School, and Dr. Chapman. When they left, the officers shook hands with Dr. Warren and told him that if they had not expected him to become a consultant in the project they would not have met with him.

Luncheon had been brief, and the discussion after it had not lasted more than 15 minutes. The psychologic impact of the technique used was enormous, and the preparation for the interview, Dr. Warren found later, had been thorough. The two officers had called upon President Valentine, asked his permission to enlist the services of one of his faculty, and given him the name of Dr. Conant, President of Harvard University, as their reference. When Dr. Valentine phoned President Conant, he was told that the project in question was "a very important war program," and that he should agree to whatever the officers had asked of him.

Under these circumstances, Dr. Warren became a consultant to the Manhattan Engineer District on 2 March 1943, within 2 weeks after the original interview.

Major Friedell, then a civilian, was engaged in much the same manner. He had worked with Dr. Stone's group at the University of California in San Francisco, and in early August 1942, he was hesitating between a third year of training or volunteering for the Medical Corps; he was unwilling to enter service unless his training and interest in radiology could be utilized. At about this time, the laboratory was visited by Colonel Nichols, assistant to Colonel Marshall in the Manhattan Engineer District, who was reviewing OSRD contracts held by Dr. E. O. Lawrence (p. 833). Colonel Nichols promised Dr. Friedell that if he would accept a commission in the Medical Corps at once, he would be very helpful in a program that Dr. Stone had already agreed to join (the University of Chicago Metallurgical Laboratory). Dr. Friedell accepted the proposal without any more information concerning it, was commissioned at once, and was assigned to the Manhattan Engineer District as its first medical officer. Late in August 1942 he was sent to Chicago to join Dr. Stone.

The secrecy imposed on the officers and civilian workers in every phase of the development of the atomic bomb extended to their families. When Dr. Stafford L. Warren was commissioned in the Medical Corps in November 1943 and was assigned to Oak Ridge, his family, for security reasons, moved there also, as did the families of many of the other workers there. Mrs.

Warren did not know until after the war had ended what her husband or any of his associates were doing, and other wives were similarly ignorant. In the beginning, there was no social life at all in the 58,000-acre barbed wire enclosure. Families were allotted houses on the basis of the number of children they had, not by rank. Children were registered in school by their first names only. No one was permitted to say whence he came or what he was doing. Pseudonyms were often used. Physicist Arthur Holly Compton was Mr. Holly. Dr. Urey was Mr. Smith. When some one indiscreetly mentioned heavy water at a dinner at which "Mr. Smith" was present, Mrs. Warren realized who their guest was, though she had no idea what he could have in common with her husband, whose specialty was radiology.

The men kept quiet about their work because they were ordered to. Their wives and families kept similarly quiet about everything, for fear, or as a matter of honor, or because they really though it was better to know as little as possible. Dr. Warren was guilty of one breach of security: His two teenage sons rifled his pockets, after one of his trips, for match folders, which, when they laid out, enabled the boys to trace his journey from Rochester, N.Y., to Hanford, Wash. All that he said to them, Mrs. Warren recalls, was "touché," but "something in the way he said it made them know that this time it wasn't a game of cops and robbers."

DOSAGE TOLERANCE

The first quantitative statement concerning tolerance dosage of X-rays, later referred to as the MPD (maximum permissible dose), was made in 1934, by the International Commission on Radiological Protection. It was set at 0.2 r per day (*6*). In 1936, the U.S. National Committee on Radiation Protection and Measurements set the level at 0.1 r per day, a level that was maintained throughout the war.[4] In 1938, the same Committee also set a "*permissible body* burden" for radium at a level of 0.1 microcurie. Although these levels were accepted by the national professional organizations concerned with radiology, it was clear to all that they were speculative end-points, not substantiated by any existing data.

Therapeutic Doses

During the 1930's and early in the 1940's, commercial designs of X-ray machines were greatly improved and high energy radiation sources became more available. As a result, there was renewed interest in the physiologic

[4] In 1948, the tolerance dosage was reduced to 0.3 rem per week, and in 1957 to an average of 5 rems per year. The permissible radium level was not changed. At the present time (1965), the radiation exposure standard has been reduced from 0.1 r per day for a 5-day week to 0.3 r (0.3 rem) for a 5-day week, or 5 rems per year. There is still, however, no satisfactory body of substantiating experimental data to support this level. Satisfactory evidence of the safety of these doses would require extensive, careful, fundamental research carried to a significant end-point through the life time of a large species.

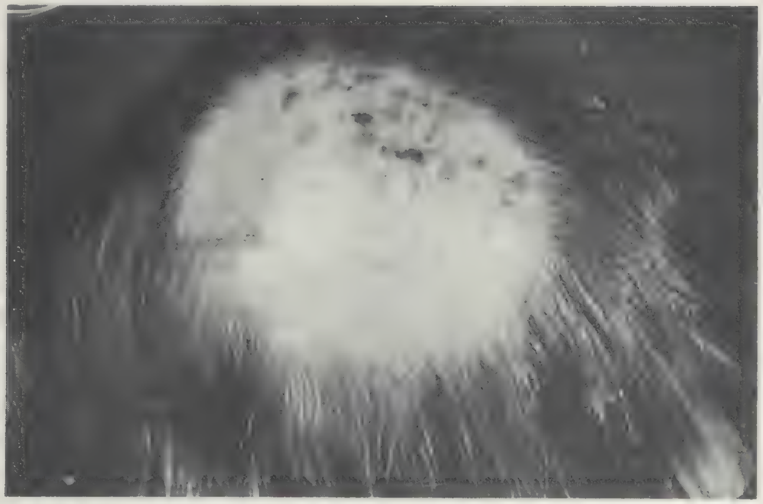


FIGURE 284.—Typical epilation and scarring of scalp after radiation therapy for ringworm.

effects of radiation of various intensities on organs and tissues of varying sensitivities. A further result was that it became possible to give higher depth doses for deep-lying tumors with, at the same time, less severe skin damage at the site of treatment.

Cancer clinics all around the world had for a long time been using various X-ray techniques, with and without surgical removal of the cancer. They were also using combinations of radium and X-rays over limited areas of the neck, pelvis, lip, and other parts of the body. Courses of treatment for carcinoma of the lip extending over 6 weeks and totaling 4,000 r were not unusual. Healing was quite satisfactory. All areas so treated, however, were very small. Larger areas were treated much more conservatively. Injuries of the bowel and bladder were not infrequent sequelae of the first attempts at pelvic irradiation for cancer of the cervix, with 200-kv. X-rays alone or in combination with applications of radium to the cervix.

Recognized dangers of radiation included cataracts (*7*); loss of hair after treatment for ringworm of the scalp (fig. 284) and at other portal sites and its return with pigmentary and structural changes; erythema of the skin with pigmentary changes, atrophy, and scarring; desquamation of cartilage and even of bone; damage to the bowel and bladder; and temporary destruction of lymphoid and splenic tissues. All of these sequelae were well known, but there was little systemic understanding of the mechanisms that caused them.

Coutard and his followers (*8*) developed very high repetitive dosages schemes that resulted in advanced stages of desquamation and inflamation of the skin and mucosal surfaces. These severe reactions were followed by healing and depigmentation, as well as by various degrees of scarring and degen-

eration, but they were also followed by improvement in the 5-year cures (control) over previous results.

As time passed, dosage comparisons became possible because of the introduction of standardized dosimeters; the Victoreen r-meter was most commonly used in U.S. clinics. All these instruments and radiation source standards could be calibrated in the Radiation Laboratory of the National Bureau of Standards (*6*). This laboratory, which was established in 1927 as the result of pressures by the radiologic profession, was able to calibrate instruments after 1929. In 1928, it employed three persons; in 1960 it employed 100.

By the time the United States entered World War II, a large body of knowledge had accumulated in the cancer clinics of the country, as well as in Canadian and British hospitals, from direct clinical trials in advanced and hopeless cancer with higher and higher energy X-rays (from 200 to 1,000 kv.) (*9–13*), and with gamma rays of radium salts and radon seeds and neutrons (*14*, *15*). The knowledge was empirical, however, and it concerned only restricted areas of body and specific organs, including the lips, tongue, skin, especially of the face, larynx, breast, and cervix.

Experimental Studies

In April 1942, when Dr. Warren was serving as civilian consultant to the Manhattan Engineer District but still had not been informed of all the details of the program which it had underway, he and Major Friedell agreed at one of their conferences that certain experiments should be undertaken at the University of Rochester Medical School, these investigations to include tolerance levels and genetic low level radiation exposure (daily exposures at the 0.1 r per day level), as well as a search for improved instruments and the development of techniques to carry out the tolerance studies. No explanation was given of the need for such studies, and Dr. Warren, convinced that they must be of great importance, asked no questions.

An office was promptly established at the University of Rochester, and an area engineer, Capt. (later Lt. Col.) E. L. Van Horn, CE, was assigned to the laboratory, which was enlarged to accommodate the planned experiments. A million-volt X-ray machine was already available (p. 835). The studies just mentioned were carried out, as well as studies on the deposition of heavy metals in bones (Dr. Hodge) and on instrumentation (Dr. Bale).

Early in 1944, Dr. Dowdy began to test doses above and below 0.1 r per day for 5 days a week in primates, dogs, rabbits, rats, and mice; his studies included genetic observations. Experiments on fertility and genetics were carried out by Dr. Stern on *Drosophila* flies and by Dr. Charles on mice. In 1945, somewhat similar studies were carried out at the National Institute of Health by Egon Lorenz, Ph. D., who used very small doses from a radium source over long periods of time.

Another series of experiments was carried out at the University of Wash-

ington School of Fisheries by Lauren R. Donaldson, Ph. D., with Columbia River salmon and trout. X-rays were employed because there seemed no feasible way of utilizing either mixtures of internal emitters from the Hanford piles or long-term exposures. Massive single doses were therefore employed at 180 kv. over a range of 20–100 roentgens in both males and females and in artificially fertilized eggs. Some interesting genetic observations were just beginning to be made when the experiments were terminated with the end of the war.

Maximum Permissible Dose

Up to 1943, not much attention had been paid in the uranium program to MPD standards because the quantities of radioactive materials being produced were relatively very small. With the expansion of the program and the development of the chain-reacting piles, it became necessary to establish shielded and protected working conditions. The first consideration was the maximum permissible dose. After extremely serious consideration of added costs and probable delays if levels should be changed at any later time, it was the official decision that 0.1 r per day should be the total external body maximum permissible dose.

A large factor of safety was required because of the very large extrapolation of findings from the fly or the rat or mouse to man. There was therefore extensive consultation before the MPD and other standards were determined. It is interesting and gratifying to realize that the positions taken in 1943 are for the most part still (1965) valid. Postwar research has refined some of the end-points by less than an order of magnitude, and more is now known of the laten effects of radiation than was then even suspected, but there has been no major alteration in any of the postulates then employed.

RADIATION AND OTHER HAZARDS

In May 1943, Dr. Warren and Major Friedell attended a conference with Dr. Stone's group at the University of Chicago, at which the wide ramifications of the Metallurgical Laboratory there were reviewed—and most of the facts concerning the development of the atomic bomb were disclosed to Dr. Warren for the first time.

A great deal of experimental work had been carried out by the Chicago group since Dr. Stone's arrival 9 months earlier. The Fermi pile had gone critical on 2 December 1942, and the physicists and chemists engaged in the project, working under Dr. Compton, together with the engineers of the E. I. du Pont de Nemours & Co., were just beginning to design the pilot plant to be built at Oak Ridge (the Clinton Engineer Works). Although the designs for the piles at Hanford were barely started, it was already evident that the radiation problems of the larger piles would be similar, but vastly greater, than the problems of the pilot pile at Oak Ridge.

Uranium X1 and X2

All four methods for producing material for the bomb from uranium, as either the common or the rare isotope (p. 839) or as the new plutonium were employed at Oak Ridge. Three of these methods were assumed to carry only the hazard of radioactivity caused by constant accumulations of uranium X1 and uranium X2. For every ton of uranium metal (element) produced, or for its equivalent in ore or concentrates, some 40 curies of X1 and X2 were formed naturally every 90 days. Discards formed a special problem when either extraction of uranyl nitrate was employed, and their storage would obviously present major difficulties if and when the production rate became greater, particularly if the discards contained radium salts, as they frequently did.

The three isotope separation methods that accumulated uranium X1 and X2 were the electromagnetic separation process designed by E. O. Lawrence (Y–12); the selective filtration or barrier process designed by Urey (K–25); and the thermal diffusion separate schedule designed by Abelson (S–50). The fourth production method, the Chicago pilot pile (reactor, X–10) or chain-reaction procedure, was designed to produce plutonium (Pu–239) from uranium (U–235). In the course of the chain reaction, a great many radioactive emitters were produced, each of which had to be regarded as a possible hazard. In addition to the risks of external exposure of workers, there also had to be taken into consideration the possible ingestion or inhalation of these substances (p. 862), or their introduction into the body by some other means, or their loss as stack effluent into the air or into the cooling water systems.

Contamination

When radioactive tracers began to be used widely, problems of contamination began to show up in the laboratory, and waste disposal procedures had to be designed. Since radiologists were already aware of the hazards of repeated low level exposures to radiation, there was already a good deal in the literature about shielding and protection from increasingly higher energies of the diagnostic and therapeutic beams by the use of barium plaster and lead-lined and concrete walls in new hospital installations (*10, 16–20*). Some standard criteria for levels of protection were in order, since protective shields in the plants were expensive, and their weight created structural problems.

Ashes and Wastes

A great deal of work was carried out in the laboratories at Oak Ridge on the safe handling of radioactive ashes and waste products left after the extraction of plutonium from U–238. Even though the extraction was accomplished by remote control, with heavy shielding, occasional hazards

had to be circumvented. New designs and procedures would be necessary to eliminate them in the Hanford operation, in which the amount of radioactivity would be fantastically greater than at Oak Ridge and the Chicago Metallurgical Laboratory. Moreover, the hazards, even with uranium X1 and X2, differed from site to site in the kind of discards and the amounts.

The area engineers usually solved these problems for a group of industries by stockpiling the discarded waste radioactive materials in a carefully selected location, which was not subject to flooding or excessive erosion from heavy rainfall, so that contamination would not be be introduced into a river or lake that was an actual or possible water supply. Some sort of barrier was erected around the location used. In other instances, waste materials were stored in abandoned reservoirs, with the expectation that some better solution would emerge after the war.

The ashes from the piles at Hanford and the radioactive material left when the uranium was bombarded in them were another matter. By the time the extraction had proceeded long enough to produce the material necessary for a number of bombs, there would be a sizable storage problem for these materials, both in solution and in precipitates.

A number of wells were drilled to test the isolation of various areas in the Hanford site, to be certain that the stored materials would not enter either the water table or the Columbia River. At both Oak Ridge and Hanford the best solution was the building of huge underground reservoirs, with double concrete walls.

Dusts

Dusts were important for two reasons:

1. They were radioactive and therefore might cause damage from the emitted radiation if they were inhaled or ingested.

2. They were often toxic.

Chambers in which animals could be exposed to dusts and fumes were not well developed at this time, and there was no precise way of calibrating the dosage received by an animal exposed at a presumed concentration of dust in such a chamber. Further uncertainties were introduced into the experiment because of the animals' habit of licking their fur after the exposure, thus complicating the chronic experiment by the amount of material swallowed.

At Berkeley, Dr. J. G. Hamilton and Dr. Scott solved this particular difficulty by giving rats a single exposure of short duration, with only the head completely exposed. No solution, however, was found for the technical problem of repeated daily exposures.

Inhalation Hazards

Studies on inhalation risks were carried out chiefly by Dr. Hodge at the University of Rochester and Dr. Albert Tannenbaum at Michael Reese Hos-

pital in Chicago. Two important conclusions emerged from their work:

1. A considerable excretion of inhaled particulate matter into the throat was caused by the movement of cilia in the larger bronchi.

2. A great deal of potentially dangerous material was therefore probably absorbed by ingestion rather than by inhalation.

Great reliance was placed on the results of chronic toxicity experiments performed by feeding test salts to mice and rats over 30- to 90-day periods at low dosage levels. These experiments were usually carried out simultaneously in the laboratories at Chicago and Rochester, with only minor procedural differences, so that one series would serve as a check on the other and the experiments would not have to be extended unduly or repeated.

Other Hazards

Radiation was not the only hazard encountered in the development of the atomic bomb:

1. Uranium hexafluoride, an important form of uranium employed in very large amounts in several stages of the program, also introduced hazards. Elemental fluorine gas used in its manufacture was found to ignite and burn up valves if a speck of carbon were left in the valve seat or aperture. Some short-term but extensive experiments showed that the risk here was not from the effects of inhaling the gas but from the high temperature of the fluorine flames. Hazards to the local population could occur if large amounts of fluorine or fluorides were to be discharged in effluents in any quantity. These hazards were studied, and contractors were advised of the precautions that should be taken to avoid them.

2. Beryllium was fabricated in large amounts in one stage of the process, and several acute pulmonary-circulatory injuries occurred before this risk was realized and controls and preventive measures were introduced.

3. The toxicity and toxicology of a great many new solvents was entirely unknown, and all of them had to be tested quickly. Since many of them were employed only to clean pipes and other gear during the installation of plant equipment, special precautions were developed for this single handling, but no extensive toxicity studies were made.

4. Carbon tetrachloride, which was used as both a cleaning and a reacting agent in various chemical chlorinating reactions, was an occasional hazard, particularly if it came into contact with a hot plate or gas and produced phosgene.

DEVELOPMENT OF THE HEALTH-SAFETY PROGRAM

Concept of Safety Precautions

Several fortunate circumstances combined to make it appropriate and possible to introduce safe practices from the very beginning of the uranium

program, although they were somewhat crude as compared to the more refined practices later introduced:

1. Industry had long recognized the wisdom of protecting workers from noxious and hazardous materials (*21–26*), and compensation insurance against injury in hazardous occupations was well established.

2. All radiologists and scientists, from reports in the literature or their own past experience, were aware of the risk of exposure of the body to penetrating radiation, even in small amounts (*27*). Bone and marrow damage had been reported by Martland and his associates in 1925, in workers on radium-painted dials (*28*), and similar hazards from inhalation of radon in laboratories were also recognized. It was generally assumed also that radioactive materials in sufficient concentration could produce tissue damage on inhalation or ingestion.

3. Radiologists and physicists associated with them in the treatment of cancer with high energy radiation from X-ray units and with radium, as previously pointed out (p. 845), had already worked out protective measures, and fairly reliable instruments were available (*29*). Thus a body of knowledge and protective policy already existed in principle, although it was adapted only to isolated units and rather low levels of operation.

4. Radioactive isotopes (p. 835) were beginning to be used with considerable frequency in many university and other research laboratories for biologic tracer studies (*30*, *31*). The amounts used were small, but the materials had to be handled carefully, and decontamination and disposal procedures had to be worked out even for them. Interestingly enough, the compelling need for these safety procedures was not so much the hazard that was beginning to be recognized as it was the local interference with the measurement of isotopes (the so-called background count) if precise techniques of use and disposal were not enforced.

In spite of the realization of the hazards of radioactive materials just described, little formal attention was at first paid to the health and safety aspects of the OSRD program. Uranium was being produced in only small amounts in laboratories and for experimental purposes. Various contractors, it is true, had carried out bulk reduction of ore to oxides, but the amounts of ore they handled were relatively small, and production of uranium oxide was still on a small scale. University research chemists, physicists, and radiologists carried out their research activities as individual groups, and when, occasionally, a physician, usually from the student health department, was questioned informally about the toxicity of these materials, he seldom knew the answer.

Special Precautions

Where the need already existed, the beginnings of a specific, effective health and safety program had already been developed in some laboratories. In Berkeley, Dr. E. O. Lawrence and his group did their principal work on the electromagnetic (cyclotron) separation of U–235 from U–238 in their

own laboratory, where the hazards of neutrons, radioactive targets, and materials made in the cyclotron were fully realized. The personnel were well protected by the measures outlined by Dr. J. H. Lawrence and Dr. J. G. Hamilton (p. 845). On the San Francisco campus, Dr. Stone was equally active in protecting his workers. Most of the safety procedures later set up were adaptations and expansions of the elementary radiochemical methods developed by the workers in the cyclotron programs. They were, of course, expanded to almost astronomic proportions in the industrial production of uranium that got underway a few years later.

At any rate, when the uranium program was begun, the principles of safe handling of radioactive materials, although still in their infancy and applied on only a small scale, were ready to build on, and some laboratories already had effective programs.

In the early days of the program, the policy was to avoid all radiation exposure, a desirable goal but one that proved impractical in some situations. It was therefore necessary to set minimal daily dosage standards for various types of radiation, such as gamma rays of various energies, beta rays, alpha emitters, and neutrons.

In January 1942, when Dr. Compton's group at the University of Chicago agreed to concentrate their experimental work on plutonium, plans were already well advanced for developing a uranium pile to produce the chain reaction from which the plutonium was to be derived. The process would be associated with the production of neutrons and radioactive products of fission in amounts never before handled. Moreover, the exceedingly radioactive uranium slugs (biscuits) would have to be extracted chemically for their plutonium content, and thousands of curies of radioactive fission products would be left over in the discarded waste.

At both Oak Ridge and Hanford, the possibility had to be considered that one of these radioactive slugs might rupture in the reaction. Another possibility was that certain radioactive gases would come out in the ventilation process and escape through the chimneys of the piles. A good deal of study was devoted to both problems in both locations by Phil E. Church, Ph. D., who made a complete investigation of the local meteorologic conditions. Although inversions were common in both areas, there was, fortunately, no escape of dangerous amounts of either radioactive or noxious materials that might harm the population.

Eventually, many production procedures were carried out in closed cycles, without human contact. In experimental laboratories, however, where scientific and engineering groups worked in pilot-sized numbers with relatively large amounts of radioactive materials, stringent precautions were always enforced. Until the end of the war there was a constant search for improvement in the chemical separation of plutonium from the mass of fissioned products and unfissioned uranium in solution or in precipitates produced by dissolving the bombarded uranium. Constant supervision was

FIGURE 285.—Safety shower at Chicago Metallurgical Laboratory. In areas such as these, personnel whose clothing was accidentally contaminated with radioactive materials could strip quickly and shower thoroughly. Contaminated clothing was handled in a special laundry.

necessary to be sure that the safety precautions laid down were not relaxed at any level of the operation and that no changes were made in it.

Once standards for exposure were agreed on, each industrial process could be analyzed, and the protection necessary could be predicted. The necessary measures varied from personal hygiene (fig. 285) and control of clothing in the so-called changehouses (p. 865) to control of ventilation and of air content. It was not only necessary to protect against total or partial external exposure (hair, nostrils, hands, genitalia). It was also necessary to control exposure from absorbed and internally located radioactive emitters resulting from inhalation, ingestion, and trauma.

If the special construction and other procedures required to protect personnel against radiation and radioactive material could have been reduced or eliminated, it is probable that the atomic bomb could have been produced for considerably less money and in a much shorter time. The shielding and ventilation requirements of uranium and plutonium production and the fab-

rication of the bomb created enormous structural problems. Radiation and radioactive material from a large variety of sources and in incredibly large amounts were serious controlling and limiting factors during the total process. Remote control and protective personnel measures were necessary wherever radioactive materials and noxious chemicals were handled. Whatever these precautions may have added to the program in terms of time and cost, they were uniformly successful in the protection of the personnel engaged in it.

DEVELOPMENT OF RESEARCH PROGRAM

During the preparations that preceded the entrance of the United States into World War II, as well as early in the war, both the faculties and the administrative personnel of medical schools and allied institutions often found themselves frustrated by the uncertainty of their position in relation to the war effort. Even with a contract from the OSRD Committee on Medical Research, the responsible investigator could not be assured of high priority in research material or of deferment from military service for himself or his associates. It had apparently not yet been realized that time could be saved by increasing the scope and pace of individual research by the grant of more funds to provide more adequate staffing and facilities.

Military hardware factories and other plants manufacturing war materials were given priority ratings for the personnel, equipment, and supplies required by a large military machine. No one seemed to have thought of a similar system of priorities for important areas of biologic and medical research. Even as late as 1943, investigators in these fields had to justify, in competition with soldiers and bullets, their absorption of manpower, equipment, and materials.

It was the policy in the S–1 Section program of the OSRD up to 1943, and thereafter in the Manhattan Project, to set up research and training programs in institutions and departments that had displayed a previous interest in the field of radiation and radiation effects. There were also many programs not directly involving radiation or radioactivity per se, particularly in toxicology, in which special experimental biologic competence was required.

Thanks to its high priorities and ready funds, the Medical Section, Manhattan Engineer District, was able to utilize highly qualified investigators in university groups who either had no research on hand or who had only small OSRD contracts, on which the pace was slow because of inadequacies of manpower and equipment. In such instances, the Medical Section had to exercise diplomacy and discretion in order not to hamper the OSRD project by giving the investigator a new and more urgent assignment, as well as, for security reasons, not to disclose the existence of a competing government group. It was sometimes necessary for the investigator to wait until the fiscal year was up and then not ask for a renewal of his contract.

Occasionally the OSRD grant was supplemented by providing laboratory equipment with which the investigator could wind up his work more promptly. In some instances, the equipment for the MED project was installed before the OSRD project was completed, so that no time would be lost in beginning the work.

The Medical Section personnel were usually able to convince the investigator they wanted that the proposed project was essential to the war effort. Most important, perhaps, was the provision of an adequate budget, usually for the first time in the investigator's experience. With the assumption of the MED project, his time and strength were often taxed to the breaking point, but the work was somehow done, and usually done well.

Data on Effects of Radiation

A considerable body of experimental data was available, upon which further investigation could be built, when the Medical Section, MED, was constituted in August 1943 (*32*). It was not so useful as it might have been because prewar experiments were usually devised with the purpose of creating pathologic lesions by irradiation in order to elucidate organ systems and functions rather than solely to study radiation effects. The available data were derived from work on genetics (*33–36*), on the intestines (*37*, *38*), and on the hemopoietic system. The blood studies were particularly concerned with the life expectancy of the red blood cell and the platelet and their precursors in the bone marrow (*39–41*).

Short-term experiments by Dr. J. G. Hamilton had showed that many very vigorous alpha emitters were also bone-seekers and were likely to damage the human hemopoietic system. Large-scale ingestion and inhalation experiments were regarded as too hazardous and too costly to undertake. They were really unnecessary, since the studies just mentioned had showed that the risk of these emitters was present even in very low concentrations. On the basis of these preprogram studies, handling and ventilating precautions were instituted wherever alpha emitters occurred.

Since many of the heavier metals were used in great quantities with various salts and various valences, Hodge, in 1943–44, ran a rather extensive series of feeding, inhalation, and injection experiments with some of the more commonly used of these metals. He verified that uranium was excreted by the kidneys, with some damage to the glomeruli and tubules. On the basis of this observation, physicians in plants in which uranium salts were handled in large quantities were directed to carry out tests for albumin and phosphatase in the urine, in order to determine, from the pilot survey, how serious this damage was. In the few cases in which renal injury was detected, investigation showed that the workers affected had not observed the specified precautions, which were forthwith tightened up. With these exceptions, all examinations were negative for albumin and phosphatase, and the investigation was discontinued.

The extensive feeding and ingestion experiments carried out by Tannenbaum and Hodge (p. 855) also showed that the kidney that had been damaged was likely to become resistant, the damaged areas healing with no residua of injury. As long as the dosage of uranium was maintained at a low level, albumin and phosphatase would not be excreted in the urine, though the original damage would recur if the dosage was increased.

Development of Instruments

While the development of instruments is not ordinarily classified as research, a most important feature of the control and safety aspects of the Manhattan Engineer District program was the steady improvement in the accuracy and reliability of the instruments used for measurement of radioactivity (fig. 286). Equally important was the reduction in their size and weight. These instruments, to be fully useful, had to be portable, rugged, and capable of maintaining their calibration under extreme conditions of heat, humidity, and transportation. In other words, they had to be both precise and convenient to handle.

The rapid adaptation to biologic experimentation of the Geiger-Müller counter was spectacular. It was used successfully for tracer purposes both experimentally and clinically.

Many institutions before the war built their own counters. Two techniques were widely used, the dry-ash, flat-dish technique and the wet-ash dipping technique. At the University of Rochester, in June 1943, Dr. Bale built a portable, battery-operated Geiger counter, with a probe and 10-inch speaker (*31*). It weighed about 40 pounds and fitted into a large suitcase. It was extremely useful in the industrial inspections that were part of the Medical Section's functions (p. 869).

An extensive study of film badges was made at both the University of Chicago and the University of Rochester, in an attempt to obtain, from the density of the silver deposit on the film, a standard measurement, and also to distinguish the various energies of the neutron-measuring device. Gioacchino Failla, D. Sc., at Columbia, and Dr. Wollan, at Chicago, were among those who devoted a great deal of time to devising a suitable field method for measuring alpha emitters and neutrons.

By early 1945, standards of measurement and calibration had been well worked out. The film badge and the Lauritsen pencil electroscope were standard equipment in all areas in which there was any exposure to radiation, and logs were kept separately for individuals who worked in them.

Others who participated in the development of instruments before and during the war were Dr. Rose, Dr. Morgan, and Dr. Parker, at the University of Chicago, and Malcolm Watts, M.D., at Los Alamos.

FIGURE 286.—Measuring instruments used to monitor plants and other areas for radiation hazards. Monitors wear protective clothing. A. Long-handled probe. B. Beta-gamma survey instrument carried by worker fully equipped against radiation contamination hazards. Note mask, gloves, canvas bootees, badge, and pencil radiation meter. C. Fish-pole meter. D. Probe counter used to examine container during transportation for radiation leakage. Note washable uniforms, radiation measuring film badges, and pocket pencil-size radiation meters on chest.

DEVELOPMENT OF HEALTH-SAFETY PROGRAMS

University of Chicago Metallurgical Laboratory

Early organization.—In August 1942, Dr. Stone, Professor of Radiology and Chairman of the Department at the University of California School of Medicine in San Francisco, accepted the newly created position of Associate Project Director of Health in the University of Chicago Metallurgical Laboratory (*42*). As soon as he was appointed, he was made a member of the Laboratory and Project Councils, which placed him on a level with the Directors of the Nuclear Physics, Technical, and Chemistry Divisions. He could therefore offer advice on necessary protective measures during the planning stages of the work instead of after health and safety problems had arisen.

Dr. Stone was able to assemble a group of workers at the Met Lab who were capable of dealing with radiation hazards from the planning stage of the problem, as just noted, through the completion and operation of the production piles in Hanford in 1944–45. Sound as was the policy of advance medical planning, it was not a usual one at this time. Because it was initiated by a scientific group of established reputation, this practice became standard policy and was promulgated throughout the pilot and production programs by the Manhattan Engineer District and by all contractors. It can fairly be said that this practice was, in large measure, responsible for the success of the protective measures employed and the greatly reduced risks of an inherently hazardous operation.

By the end of 1942 (that is, by the time the Fermi pile had gone critical), Dr. Stone, with the assistance of Dr. Cantril [5] and others, had coordinated all biologic research for the Laboratory and had developed safety procedures and training exercises which were later applied at the Oak Ridge pilot plant (Clinton Engineer Works) and at Hanford.

The program was operated by three separate groups:

1. A Health Group (Drs. Jacobson and James J. Nickson). This group performed routine physical examinations and made blood counts and urinalyses for all personnel employed in the Met Lab.

2. An Instrument Development Group (Drs. Rose and Wollan). This group designed and calibrated Geiger counters, ion chambers, and electroscopes of various sorts for monitoring purposes and for laboratory use; film badges of various designs; and other instruments for detecting radiation, including alpha particles, beta electrons, and neutrons.

3. A Biological Radiation Effects Group (Dr. Cole and Clifford L. Prosser, Ph. D.). This group endeavored to define the mechanisms of radiation injury, whether from external or internal exposure, in the hope of detect-

[5] Dr. Simeon T. Cantril, a brilliant and well-qualified radiation therapist (*43*), also spent considerable time at the Oak Ridge pilot plant, at the Berkeley Radiation Laboratories, and at Hanford, training personnel. He was also consultant to the School of Fisheries program (p. 878). Later, he went to Seattle, to direct cancer research at the Swedish Hospital, where a million-volt X-ray generator was being installed.

ing incipient or early and minor changes and providing countermeasures which would prevent or heal these injuries. Inhalation and ingestion of radioactive materials were of particular concern (p. 855).

All of these activities were so organized as to enable the Medical-Health Group to keep ahead of design schedules. Because of the time occupied by a single experiment, it was immediately evident that each one could be conducted only once and must be carried out the first time on a large enough scale for results to be significant. The biologic group therefore worked at a rapid pace and used experimental animals in numbers never before contemplated in medical research.

Special protective measures.—The protective measures instituted at the University of Chicago Metallurgical Laboratory were thorough and comprehensive, since, as already stated, those developed for the chain-reacting pile here would be used, in turn, in the pilot plant at Oak Ridge and then in the production piles at Hanford.

The training program set up for contractors' personnel involved testing and perfecting a dry-box technique (fig. 287) for handling materials inside of a box while controlling the operation by vision through a lead glass window; devising suitable clothing, including gloves, shoes, and masks (fig. 288); and development of laundry procedures for cleaning clothing and other materials that had become contaminated. The last of these functions required a search for efficient solvents and so-called complexing materials.

At first, surgical soap and, in extreme cases, aqua regia, were used to cleanse badly contaminated hands. Later, some of the newly devised commercial detergents were substituted and proved most effective.

Since clothing, shoes, and gloves were readily contaminated, so-called changehouses were set up in which clothing worn at work could be exchanged for fresh clothing. The houses were so designed that there was an area of transition from dirty to clean space, and they were amply provided with lockers, showers, and washbasins.

At the beginning of each shift, as the workers reported, clean gowns, jumpers, and coveralls were issued at the entrance of the house. Street clothing was removed and stored in lockers, and the issue clothing was donned. Before the plant proper was entered, canvas boots or galoshes were distributed, and each worker received a mask, a film badge, and a pencil meter (figs. 286B and 286D).

At the end of the shift, the workers returned to the changehouse, where their clothes and boots or galoshes were removed and inspected. Each item was cleaned and measured before it was reissued. The workers then stripped off their coveralls, turned in their masks, and walked, in their clean shoes, to the lockers, where they removed the rest of the clothes they had worn at work and where they washed or showered as necessary. Workers in particularly dusty and contaminated areas were checked with Geiger counters before they were allowed to leave. If special contamination was found on the hands or other parts of the body, official procedures for decontamination were enforced.

FIGURE 287.—Dry-box techniques evolved from wartime methods and designed to protect workers handling small amounts of radioactive materials against radiation hazards. A. Worker at Los Alamos, N. Mex., handling irradiated materials with rubber gloves inside ventilated cabinet. B. Worker at Argonne National Laboratory weighing small amount of radioactive barium in dry box, with his hands protected by rubber gloves against soft beta radiation.

FIGURE 288.—Sophisticated types of clothing evolved from clothing designed during war to protect workers against radiation contamination hazards. A. Suit made entirely of plastic, with seams zipped together to form relatively tight joints. Air from tank on the workman's back is released through nozzle in upper part of the suit to permit him to breathe. B. One-piece vinyl plastic suit, which includes the headpiece, zips up the back. Entrance to suit is through flexible tunnel at back. C. Workers prepared to enter contaminated area. Worker on right wears suit and canvas boots of type used during war. The plastic suit was a postwar development. Worker on left wears cap and mask similar to items used during war.

The workers could not escape the routine just outlined for the exchange of clothing took place just before they punched the timeclocks. Later in the program, when contamination by dust had been controlled, many workers were not required to go through the changehouse procedure.

These measures may seem elementary, but their importance cannot be overestimated. When they were put into effect early in 1944, it was clear that it would be a year or more before structural concrete of the proper thickness, ventilating devices, and other protective features of large piles could be implemented in the construction plans. These requirements had to be given to the engineers well before construction began. In the meantime, the safety of the workers depended upon the elementary precautions just described.

Other University Programs

By the end of 1944, most university pilot research programs had been turned over to industrial organizations. In the meantime, their supervision had proved somewhat more troublesome than that of the industrial field program. Since the chemistry and metallurgy of uranium had previously been of little interest, relatively little work had been done on either subject. When the necessity arose, fairly large pilot programs—almost semiproduction programs—were carried out at a number of universities, chiefly Chicago, Columbia, and Iowa State University, Ames.

With Dr. Stone and his group on guard, the health and safety problems at the Metallurgical Laboratory in Chicago were soon under control (p. 864). At other universities, the serious nature of the risk was not so readily appreciated, and proper precautions were not instituted until the staff physicians of both institutions had been thoroughly indoctrinated and had agreed to accept the responsibility for good housekeeping practices and health and safety supervision of laboratory personnel.

Industrial Field Program

The most complex and most difficult assignment of the Medical Section, MED, was the industrial field program, which ranged from discussions of design with engineers before a plant was built to the safety housekeeping techniques necessary during the processing of ore to metals. Design, construction, and operation of pilot programs were never stabilized at any single stage. They were constantly changing and being scaled upward, to enable the contractor and the personnel of the Manhattan District to obtain data for increased production.

Attention has already been directed to the continuing hazard of the natural production of the strong beta emitters, uranium X1 and X2 (p. 854). The refining process consumed a considerable amount of time, as did the shipping of the material from one place, or even one stage, to another. The hazard was therefore present from the time the ore was received at the docks

in New York from the Union Minière in the Belgian Congo, or at Port Hope, in Ontario, Canada, or from the Colorado areas, until it became a slug in a pile. Some lots of the ore were contaminated with radium and therefore gave off radon during storage. The emission of radon was a particular problem with ore from the Congo, and the drums in which it was shipped, and even the freight cars in which the drums traveled, had to be opened with special monitoring and ventilating precautions.

Plant inspections.—The inspection of industrial plants was an important part of the health-safety program (fig. 286). In May 1943, Captain Ferry was assigned to the Medical Section, MED, sent to the University of Chicago Metallurgical Laboratory and the University of Rochester Laboratory for indoctrination, and then assigned to inspection of the industrial uranium processing plants. He was later assisted by Capt. (later Maj.) Joe W. Howland, MC. Both were on the road almost continuously. The scale of operations was so large in Wilmington, Del., where the du Pont Co. was supplying material for the Oak Ridge operation and also tooling up for the Hanford operation that Capt. (later Maj.) Bert T. Brundage, MC, was assigned full time to this location. All medical officers wore civilian clothes on these trips.

With the portable Geiger counter devised by Dr. Bale at the University of Rochester, it was possible to check the situation and, when necessary, demonstrate to the contractor and his foremen that the quality of their housekeeping was sometimes not as good as it should be. The demonstration helped these personnel to enforce among the workers the precautions that would prevent accumulations of uranium X1 and uranium X2 in unwanted places and also, indirectly, prevent losses of scarce uranium salts through spillage and careless handling. The savings in salvaged uranium when undesirable practices were stopped amply repaid the cost of the changes necessary to tighten up the program and carry out the safety and health precautions.

The seemingly crude large-scale extraction procedures employed in the industrial plants were surprisingly effective. Often only simple changes were required to make them relatively clean and dust free. This was fortunate, for there was no previous medical or radiologic industrial experience upon which to draw. The industrial concerns were equally new in the field, and they viewed the arrival of the inspectors with considerable apprehension and at first with open hostility. The inspectors, by frankly admitting that their own ignorance was almost as great as that of the contractors and their personnel, soon established a basis of genuine cooperation.

Plant personnel were told frankly that certain hazards existed but could be prevented; that practices could be instituted which, if sedulously observed, would prevent harm to them; and that the precautions necessary were really quite simple and chiefly based on good housekeeping. The precautions were then listed and described. They included reduction of exposure to toxic materials and radioactive dusts, fumes, and gases; installation of showers and washbasins to improve personal hygiene; use of overalls and masks in some

plant locations, even though masks sometimes reduced operating efficiency to a considerable degree; use of film badges; and routine blood counts, to assure management as well as the plant physicians that every precaution was being taken to prevent internal injury by these new materials.

Visits to the industrial plants were made with the authorization of the area engineer, and he or an officer who represented him accompanied the Medical Section officers on their inspections. Representatives of the contractors were also present. This was an excellent arrangement. The Area Engineer could immediately authorize, under the contract, any changes required by the Medical Section officers, while the ready compliance of the contractor was assured because his apprehension concerning possible financial losses by the changes indicated was immediately allayed.

OAK RIDGE, TENN.

Oak Ridge (fig. 289) was the town constructed by the U.S. Government to provide living accommodations for personnel employed at the Clinton Engineer Works, the organization that produced materials for the atomic bomb. At the peak of operation, Oak Ridge had a population of about 71,000 persons. Approximately 40,000 to 45,000 of this number were workers in the plants (including a disproportionately large number of unmarried men). The remainder were wives and children and the service personnel who operated the town.

The functions of the town were carried out by the Roane-Anderson Co. (so named from its location, in both Roane and Anderson Counties), under policies defined by the District engineer. Before this company took over its full civic responsibilities, it operated as a subsidiary of Stone & Webster, the engineering corporation which held the contract for housing. It was paid a fixed fee and made no other profits.

Lt. Col. Thomas T. Crenshaw, CE (October 1942–May 1944), and Lt. Col. (later Col.) John S. Hodgson, CE (May 1944–January 1946), successfully served as Chief, Central Facilities Division, Clinton Engineer Works. They supervised all nonindustrial facilities and really acted as the mayor of the town during their terms of service.

The Medical Program

Dr. Stone and his group moved from the University of Chicago Metallurgical Laboratory to Oak Ridge in 1944, at a time when certain very critical pilot work was being done with the reactor there and its waste products. It was important to refine the safeguards employed in the operation of this reactor. It was also important to have ready access to a source of neutrons for animal experiments. It therefore seemed wise to bring the health-physics group to Oak Ridge and also to bring there the personnel destined to go to Hanford.

FIGURE 289.—Scenes from Oak Ridge, Tenn. (Clinton Engineer Works), where materials for the first atomic bombs were produced. A. Oak Ridge, at end of war. B. Administration building, containing offices of District Engineer, Col. (later Maj. Gen.) Kenneth D. Nichols, CE. The medical section was also in this building. C. Aerial view of gaseous diffusion plant (K–25). D. Plant (Y–12) for separation of U–235 by electromagnetic process, placed on standby after the war, is shown as modified and altered in 1953. E. Small hutments in outlying sections of city, which provided commercial cleaning, laundry, and other services for civilians. Note trailer camp in background, which housed many workers. F. Guesthouse (center), efficiency apartment building (left), and chapel on hill (rear) constructed immediately after the war.

Industrial program.—The construction companies that built Oak Ridge operated their own first aid facilities and medical care programs for their workers at the construction sites. Men with serious injuries were hospitalized as soon as the Oak Ridge Hospital could receive patients.

When the construction work was finished, the operating companies also

set up their own first aid organization, as well as an industrial medical program concerned mainly with safeguarding their workers from radiation and radioactivity hazards. Many of the personnel who were responsible for this program had been trained at the Met Lab in Chicago. They included Dr. Adolph G. Kammer (Carbide and Carbon Chemicals Co.), Dr. James H. Sterner and Dr. Christopher Leggo (Tennessee Eastman Corp.); and Dr. Stone and Dr. John E. Wirth (Monsanto Chemical Co. Clinton Laboratories).

Public Health measures.—The public health problems that promptly became evident at Oak Ridge were put in charge of Lt. (later Capt.) Bernard M. Blum, MC, in March 1944. It was his mission to see that milk was properly pasteurized; that soft drinks were free from insects (a persistent annoyance); that the bacterial counts in swimming pools were at least as low as those in milk; and that sanitary measures of all kinds were observed.

At Oak Ridge, the intake for drinking water was in the Clinch River, downstream from the sewage disposal plant. Both installations were so capably designed that safe, potable water was delivered to the town in ample quantities, a record, incidentally, that has been maintained to this time (1965).

All food handlers were required to undergo physical examinations and to be tested as possible typhoid carriers. All eating places (restaurants and sandwich and soft drink dispensing places) were inspected repeatedly. Flies and mosquitoes were almost eliminated with DDT, in an intensive drive to prevent malaria and poliomyelitis. Great care was taken to trace exservicemen and other workers who might have served, or been employed, in tropical areas. All were tested for latent malaria, but all smears were negative.

The supervisory and preventive public health measures developed at Oak Ridge were instituted in all areas under the control of the Medical Section, Manhattan Engineer District.

Hospital

Planning and construction.—In March 1943, when Dr. Warren made his first visit to Oak Ridge with Major Friedell—before he had accepted the position of civilian consultant to MED (p. 848), and when he still did not know the nature of the project in which he was being asked to serve—the 200 beds suggested for the hospital seemed somewhat excessive for an estimated population of "about 5,000." The inflated size, he was told, was necessary because of the isolation of the area and for "security" reasons. It was therefore decided to plan at first for 150 to 200 beds and to provide for possible increases in size. At the peak of operations, in 1945, the hospital (fig. 290) had 300 beds (*44*).

The surroundings in March 1943 were not promising. The headquarters of the Clinton Engineer Works were set in a sea of mud, which filled all the small valleys between oak-covered hills. Bulldozers were everywhere, and

FIGURE 290.—Oak Ridge Hospital and outpatient dispensary.

trucks carrying lumber and other building supplies jammed such roads as there were. The office for the architects who were to design the hospital (Skidmore, Owings & Merrill) was located in a shack set in the center of the other temporary buildings that served as dormitories, cafeteria, and stores. Houses being erected by Stone & Webster were in various stages of construction. The architects' shack was crowded with draftsmen, and it was obvious that other buildings than a hospital were being built.

The discussion on this trip concerned not only the hospital but also other phases of health and medical care for the town of "5,000" people who would work in the plants of this isolated region. At this time, as already noted, the contractors were operating their own medical care facilities. The following month (April 1943), a formal medical care program was set up at Oak Ridge, under the direction of Dr. Rea and Dr. William B. Holt, both of Minneapolis, Minn. The organization of the hospital was part of their responsibility.

Dr. Warren approved the site that had been tentatively selected for the hospital, a small hill at the edge of town (fig. 290). In accordance with what he was told of possible future needs of the population to live within this guarded area, he recommended that the outpatient clinic, X-ray facilities, diagnostic laboratories, and emergency rooms be expanded at once. A dental

building was also recommended, on the ground that it would save the workers' time and enhance security if this service were kept on the site.

The hospital was planned and built along modern lines and had standard modern equipment. Construction was begun in April 1943 and the first patients were received on 17 November 1943, when 50 beds became operational. The dental clinic was built the following year.

Personnel.—The Oak Ridge Hospital was operated administratively by the Roane-Anderson Co., and all of its civilian personnel were company employees. At the peak of operations, in August 1945, there were 20 civilian dentists, 141 nurses, 54 nurses' attendants, 8 dietitians, and a total hospital employment of 632, exclusive of 41 medical officers and 1 dental officer. The dental staff, organized by Dr. Harry Pitluck and 1st Lt. (later Capt.) Peter P. Dale, DC, the only Dental Corps officer in the program, was directed for most of the war by Dan Claussen, DDS, later Dean of Meharry Medical College.

Medical officers were provided for the hospital by the Office of The Surgeon General, by the special arrangements already outlined (p. 847). Under this agreement, The Surgeon General was to provide the budget for the medical care of the military contingent assigned to the Clinton Engineer Works. Since he knew no details of the operation, he must have been considerably puzzled by the large number of medical officers procured through his office for what was actually a very small military detachment. The detachment, as a matter of fact, was essentially a guard force though, at various times during the war, specialists and technical personnel, both commissioned and enlisted, were also assigned to Oak Ridge.

Most medical officers assigned to the Oak Ridge Hospital were obtained from the Minneapolis area, on the theory, borne out in practice, that men who had trained together were likely to work well together. The radiologist, Capt. (later Maj.) John B. Eneboe, MC, had only radiologic duties.

An efficient civilian staff was built up by degrees, largely by the efforts of Dr. Holt, the first superintendent. He died on 27 July 1944, but lived long enough to see the first 150 beds of the hospital in operation.

The outpatient clinic provided what was unusual for that time, a psychiatric and social welfare consultation service. The psychiatric service was operated under the direction of Dr. Eric K. Clarke and the social welfare service, under the direction of Capt. (later Maj.) William Fleeson, MC. They were later assisted by Dr. Carl A. Whitaker, Capt. (later Maj.) S. Law, and 1st Lt. (later Capt.) John Warkentin. The clinic personnel, working with the personnel officers of the industrial plants, greatly reduced the turnover of trained workers.

Workload.—Since the population of Oak Ridge was chiefly in the younger age brackets, and since all workers had had complete physical examinations before they were employed, the incidence of illness was relatively low. At that, during August 1945, there were 21,500 outpatient visits, 1,572 admissions, and an average daily census of 322. Although a poliomyelitis epidemic oc-

curred in 1944, in the area outside of the city, from which about 10,000 persons commuted to work in Oak Ridge every day, there were only two suspected cases, both mild, in the city population. The brief indoctrination the medical staff had been given in the recognition of radiation illness was fortunately never put to use.

During the approximately 3 years the hospital operated, 2,810 babies were born in it. There were 344 hospitals deaths. For security reasons, no funerals were conducted within the town, which was classified as an Army reservation, except those of a few former residents who had desired to be buried in their family plots. These funerals had Army escorts.

Insurance Program

A medical and dental insurance program was launched at Oak Ridge early in 1944, patterned after the California Physicians' Service and planned by Dr. Nathan Sinai, Professor of Public Health at the University of Michigan School of Public Health, Ann Arbor, Mich., who was an early pioneer in this field. The dental program proved financially unworkable and was soon abandoned; thereafter, dental service was rendered on a regular fee schedule.

The medical program operated well during the entire war. The charge was $2.50 per month for a single person and $5.00 per month for a family. The program was supervised by a board of trustees, at first appointed by the deputy District engineer from companies working on the site, and later elected by popular vote.

HANFORD, WASH.

There were several reasons why Hanford (fig. 291), was chosen as the site for the atomic energy project known as the Hanford Engineer Works:

1. It was necessary to conduct operations in an area large enough for reactors and population to be separated from each other by a considerable distance, in the event that one of the reactors to be built would blow out or burn up and spread contamination over a large area. Hanford was even more isolated than Oak Ridge.

2. Since Hanford was located in a bend of the Columbia River (map 10), it met the requirement for the large volume of cold, relatively pure water necessary to cool the reactors.

3. Power in the desired quantities could be secured from the hydroelectric plants at the Bonneville or the Grand Coulee Dam.

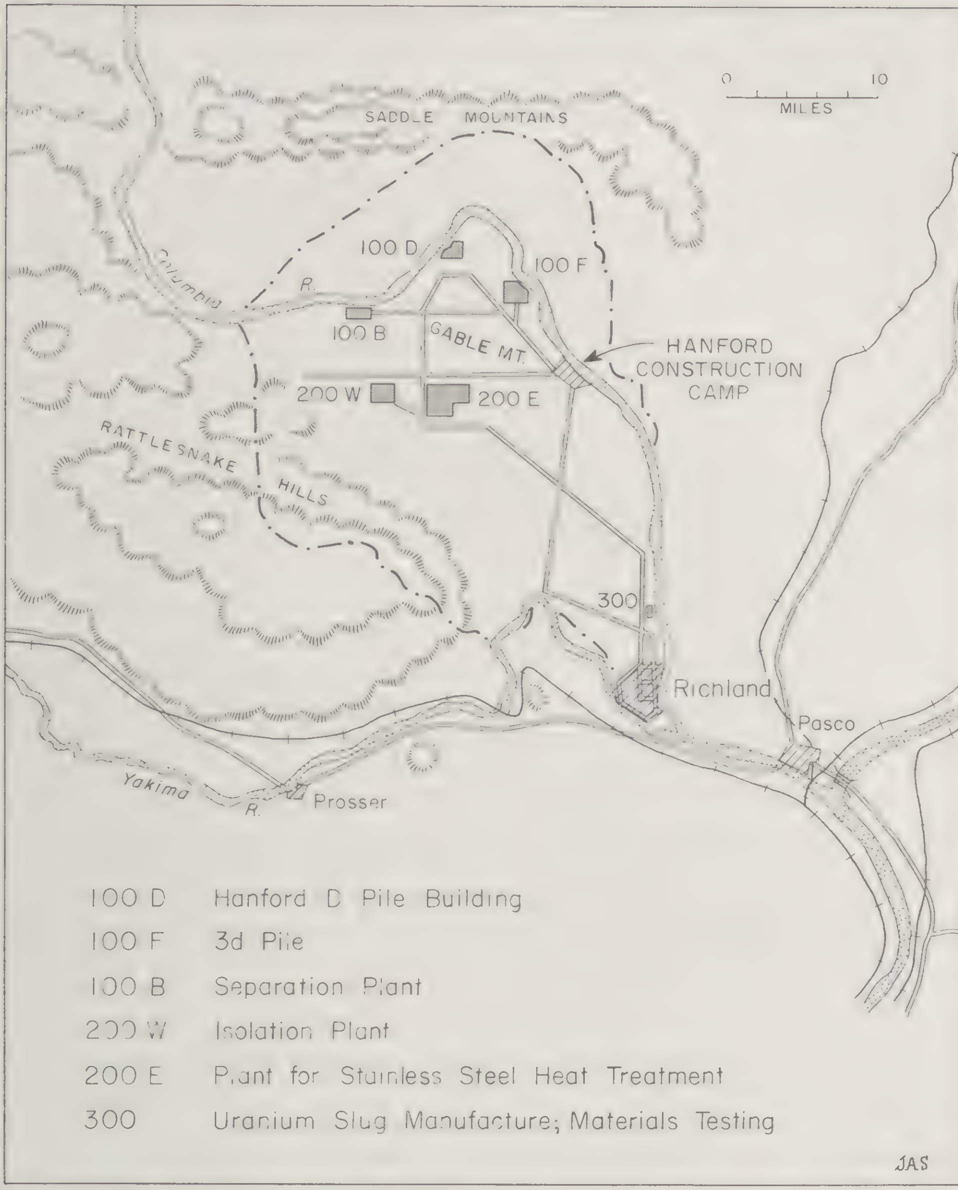
The reactors at Hanford were designed and built by the du Pont Co. The construction camp, set up in April 1943, at its peak housed 60,000 workers. After three piles were put into operation in the summer of 1944, the population fell to between 4,000 and 5,000 and was composed chiefly of

FIGURE 291.—Scenes at Richland, Wash., site of Hanford Engineer Works. A, B, C. Business development and housing, 1945. D. One of war-built reactors, where uranium was transmuted into plutonium. Several buildings in the picture belonged to the waterworks, which used the Columbia River (background) for cooling the reactor at a rate of tens of thousands of gallons per minute. E. Postwar construction camp, with trailer spaces (right, background) and barracks for single workers (center and left).

scientific and production workers. The town was operated under the area engineer, Lt. Col. (later Col.) Franklin T. Matthias, CE.

The Medical Program

Dr. Wm. Daggett Norwood served as medical director for the contractors at Hanford. He had spent considerable time in the University of Chicago



MAP 10.—Site diagram of Hanford Engineer Works on Columbia River, Richland, Wash. Note location of the construction camp housing 60,000 workers during a meningitis outbreak which could have brought the work on the atomic bomb to an abrupt halt if it had reached epidemic proportions.

Metallurgical Laboratory with Dr. Stone's group, and he had a full understanding of the industrial hazards of the Hanford operation. He was able to obtain the services of Dr. Parker, who had also trained with Dr. Stone's group and who became local health physicist in the operating plants at Hanford.

Dr. Norwood supervised the design and construction of the Kadlec Hospital, located in what is now the town of Richland, Wash., which served the Hanford population. Construction was begun in late 1943 and the hospital was completed the following spring. Its full-time staff was entirely civilian.

The health and medical operation at Hanford was extremely efficient. While 40,000 construction workers were still employed there, a number of cases of meningitis occurred. There were two deaths, but the disease did not spread and its occurrence was brief. If it had reached even mild epidemic proportions, the construction program would probably have ground to a halt, for there was an extremely limited supply of physicians and nurses in the area, the medical program was not yet fully organized, and the local hospital was not yet far enough along in construction to have handled even a mild epidemic.

Protection of the Columbia River.—The public health and other problems at Hanford were much the same as at Oak Ridge and were handled in essentially the same way. There was one special problem, however—protection of the Columbia River and its biologic contents from contamination and other effects of the production of atomic material for the bomb. Outgoing cooling water would flow into the river, and the possible changes in its temperature might have an adverse effect on both local and migrating fish. A chemical effluent from the cooling water purification process might also be harmful. Since it would be practically impossible to produce distilled water during the final refining process, the water that flowed back into the river would contain a little sodium, potassium, silver, and other elements that might have been made radioactive by neutrons as they passed through the piles.

Dr. Cantril, who had been brought into the Chicago group as a consultant very early in the operation (p. 864), was transferred to Hanford and assigned the problem of protecting the Columbia River and its inhabitants. He promptly secured the assistance of Professor Donaldson, of the School of Fisheries, University of Washington, at Seattle. Through direct observations and local experimentation, it was found possible to return the cooling water to the river at such a point in the bank, and in such a direction, that it offered no thermal barrier to migrating fish.

The water of the river was snow water and therefore almost pure to start with. The very small amounts of minerals left in it, however, after it had been purified were made radioactive while they were passing through the pile, where they were subjected to neutron bombardment. Even though the radioactivity was short lived, it was considered necessary, in order to

prevent appreciable concentrations of these radioactive materials, to keep the water in holdup ponds and to restrict the rate at which it flowed back to the river. The essential point of the method was to increase the length of the path, and therefore the length of the time, of the return flow of the cooling water.

Constant monitoring devices were installed in the effluent, and small fish were kept in tanks fed by suitable baffles from effluent waters to act as controls on the temperature and radioactive materials in the water.

LOS ALAMOS, N. MEX.

Organization and Operation

Los Alamos, N. Mex. (map 11), the site of the laboratory in which the first atomic bomb was constructed was established as a regular military post.

The first commanding officer was Lt. Col. (later Col.) John M. Harman, CE. In May 1943, he was succeeded by Lt. Col. Whitney Ashbridge, CE, and was followed in October 1944 by Col. George R. Tyler, CE, who served in that capacity until November 1945.

The Area Engineer's Office for Los Alamos was located in Sante Fe, N. Mex.

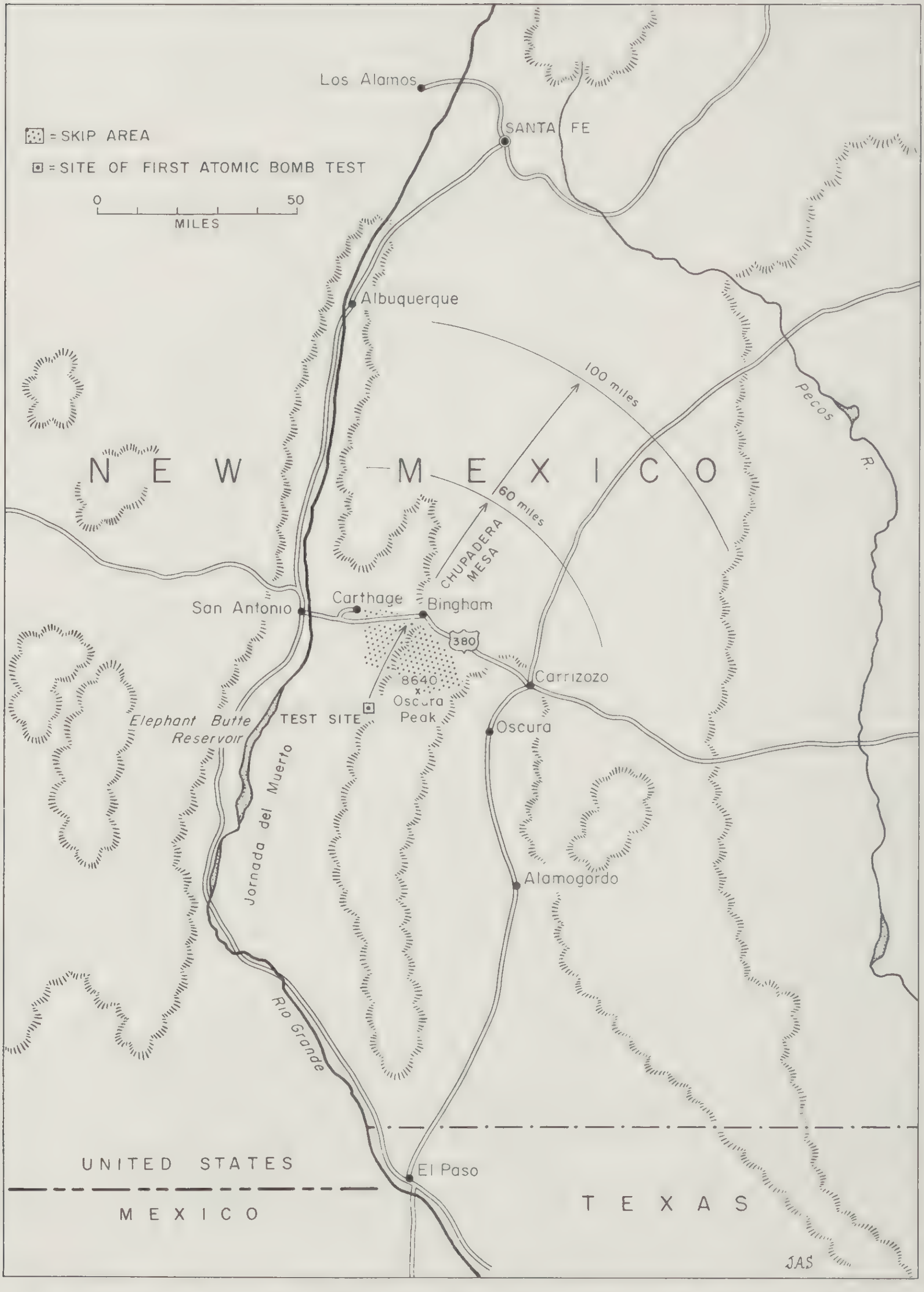
The scientific program of Los Alamos was directed by J. Robert Oppenheimer, Ph. D. The University of California served as the scientific contractor.

The medical program was under the direction of Capt. (later Lt. Col.) James Nolan, MC, whose staff of medical officers was procured through the Office of The Surgeon General (p. 847). Most of them came from St. Louis, Mo., and its environs. Health and safety precautions in the laboratories and industrial plants were the responsibility of Dr. Hempelmann. A resident veterinarian, Capt. J. Stevenson, VC, cared for the war dogs used in the peripheral guard areas and vaccinated all privately owned dogs of the resident population against rabies.

The population of Los Alamos did not rise above 5,000 at any time and was sometimes as small as 3,000. The local hospital was therefore always small, usually between 16 and 20 beds. Obstetrics and pediatrics were the busiest specialties. Hospital service was supplemented by a fairly active outpatient clinic and a small dental unit. The excellent care given by Captain Nolan and his staff to this isolated population contributed greatly to their morale and to the stability of this highly critical program.

Research Problems

Radioactivity during production of the bomb.—The problems at Los Alamos during the large-scale fabrication of the plutonium, U–235, and beryl-



MAP 11.—Area of first atomic bomb test: Los Alamos, where final preparations were made, and Alamogordo test area in the desert, where the bomb was detonated. Note skip area about 15 miles wide 10 miles from site of detonation.

lium required for manufacture of the atomic bomb were of the housekeeping variety already described. The safety precautions, which were the same as those employed at Oak Ridge and the Met Lab at Chicago, covered ventilation, decontamination, personal hygiene, and disposal of wastes.

Research problems that originated from the wide variety of experiments constantly underway with radioactive materials at Los Alamos covered beryllium dusts, nitrite effects from handling of explosives, fumes from high explosives, and solvents seldom or never previously used. Some of these experiments, which involved the use of explosive mixtures and rather wide dissemination of radioactive material, were carried out in deep canyons, so that contamination was limited to inaccessible areas of wilderness.

Laboratory space for research not absolutely essential to the fabrication of the bomb was limited, but some biologic studies were carried out on the effects of radiation and on the metabolic pathways of certain radioactive metals, chiefly plutonium and beryllium, by Wright H. Langham, Ph. D. Dr. Hempelmann, with the assistance of Dr. (later Captain, MC) Harry D. Whipple, investigated the absorption of plutonium and other metals through traumatic wounds sustained by shop workers.

Effects of the Atomic Bomb

The chief effort at Los Alamos was devoted to the design and fabrication of a successful atomic bomb. Scientists and engineers engaged in this effort were, understandably, so immersed in their own problems that it was difficult to persuade any of them even to speculate on what the after effects of the detonation might be. Their concern was whether any one of their several designs for the bomb would actually detonate, and, if the detonation did occur, how massive it would be.

Little attention was therefore paid to the possible effects of the detonation of the bomb until the spring of 1945, when the Medical Section of the Manhattan Engineer District raised the question with General Groves and was given the mission to investigate the whole matter. Two effects had to be studied, (1) blast and (2) fission product radioactivity. There was little time to spare. By May, the tower for the blast and the accessory apparatus were being erected on the flat desert at Alamogordo, 183 miles from Los Alamos (map 11), and it was apparent that the test would occur within the next several weeks.

Blast effects.—Attention was first devoted to blast effects of the bomb. A detonation on the order of several thousand tons of TNT would undoubtedly have massive effects, beginning with the formation of a lethal blast wave front.

The literature contained little on the subject except the U.S. Army Ordnance tests on goats, which had been carried out with small high explosive charges. Available data showed that lethal effects were produced by relatively high pressures, in the neighborhood of 15 psi (pounds per square

inch). Certain British studies showed that the terrain and the objects of various sizes in the path of the concussion wave produced complex reflections, skips, and concentrations. Jackets and other heavy clothing offered a degree of protection, but how much could not be determined because of lack of precise measuring devices. Debris carried by a blast wave at high velocity acted as missiles, which were often more damaging than the wave itself.

Circumstances at Los Alamos were not favorable for controlled experiments, and time did not permit them. The best that could be done was to verify the lethal effects of high explosives by hanging rats and mice on wires suspended several feet above the ground at varying distances from charges which were also placed several feet above ground. Dr. Hempelmann and Captain Nolan, who conducted these studies, found that the critical pressures covered a wide range; they began at 5 psi but were more constant at 15 psi. Part of the discrepancy was explained by irregularities of wind and terrain, and by the crude measuring devices used. Further experiments on a flat desert area with a very large chemical detonation showed that mice hung on wires 6 feet above ground would be killed by a blast wave at distances of a thousand feet and more.

Autopsy on these animals rather uniformly showed their lungs to be full of plasmalike fluid. Small hemorrhages and hemorrhagic markings were observed on the pleura, and large abdominal vessels were sometimes ruptured. If the injury did not produce these extreme effects, recovery without lasting sequelae was fairly prompt.

Radioactive effects.—The radioactive effects of the detonation of the first atomic bomb were entirely speculative. When the Medical Section, MED, asked the authorities at Los Alamos for help in this task, an advisory committee was appointed, consisting of Captain Nolan, Dr. Hempelmann, Paul C. Aebersold, Ph. D., and Joseph O. Hirschfelder, Ph. D.

It was estimated that during the detonation of the bomb, about a million curies of radioactive fission material might be released. These products—all as yet unknown—would presumably be in element form, but they would immediately become oxides and perhaps then would agglomerate with vaporized moisture and debris. It was also thought that these materials would rise very high in the large, hot, ascending cloud expected after the detonation, and that, while they were falling back to earth, they might be carried by the wind for considerable distances, perhaps even far from the test site.

Preparations for the Detonation

Over a 3-month period in the spring of 1945, Colonel Warren made an intensive study of cloud and wind situations over the entire southwestern United States. The physical geography of the country around Los Alamos was also studied, with special attention to areas of cultivation and population. The facts of the explosion in 1883 of the volcano Krakatau in Sunda Strait between Java and Sumatra, the largest such explosion of modern times, and

of a number of large military detonations were reviewed in detail, in an attempt to obtain some indication of what might be expected to occur after a detonation of the magnitude anticipated for the atomic bomb.

Alamogordo, N. Mex. (map 11), was selected for the site of the detonation after careful study of the adjacent terrain. Along the main east-west highway (380), between Socorro and Carrizozo, N. Mex., is the ghost town of Carthage, and a little further (about 10 miles) east is Bingham, consisting of a crossroads store and a windmill. The area, 40 miles square, selected for the test site had this highway as its northern boundary, with the Carthage turnoff as about its middle point. The site, which was part of the White Sands and Alamogordo Bombing Range, consisted of slightly rolling gravel desert, with little grazing potential. It extended roughly from the Sierra Oscura Cliffs on the east to the Elephant Butte Reservoir on the Rio Grande on the west and was a part of the Jornada del Muerto Desert. It is a place of great heat and drought, interspersed with violent winds and thunderstorms.

The sites for the detonation and the base camp were separated from each other by about 9 miles. The base camp served as scientific headquarters for the group preparing for the test. Bunkers and other paraphernalia were distributed about the area as necessary.

Since it was essential that the test of the bomb should be carried out in good weather, without risk of the frequent thunderstorms that occurred near Alamogordo, a meteorologist, Mr. Jack M. Hubbard, was attached to the Los Alamos Staff, and Col. Joseph Hostrum, AAF, from the Air Force Meteorological Service, was later assigned as consultant. Their studies showed that what was now coming to be called fallout might, under certain weather conditions, become a serious hazard.

A careful study of optimum test conditions was therefore undertaken. The area surrounding Alamogordo was investigated in all directions by air, on foot, on horseback, and in cars, to locate the smallest concentration of population. It was decided that the test shot should be made only when the winds at high elevations were in the northeast direction. In these circumstances, if there was a large amount of radioactive fallout, it would occur in an almost uninhabited area extending about 100 miles northeast of the test site. The wind on the day appointed for the test would thus be an extremely important consideration.

A field program was organized for local and distant monitoring, to safeguard the regional population. For distant areas, monitors were furnished with cars and measuring equipment and had radio communication with the base camp.

General Groves had been authorized to declare martial law if necessary. He had made secret arrangements with the Governor of New Mexico for procedure in the event of a catastrophe. Preparations were made to halt all air traffic between Albuquerque, N. Mex., and El Paso, Tex. (map 11), the

day of the test. All personnel not absolutely needed were evacuated from the test site. When the detonation occurred, all personnel would be at least 3 miles away in bunkers or at least 9 miles away at the base camp. Those in the base camp were directed to lie prone, with their feet toward the test tower. Dark glasses of density two or welders' goggles were to be worn by all personnel in bunkers and at the base camp. The bus loads of high officials who would witness the test were located on some low hills 20 miles northwest of the test site.

Since all personnel not needed had been evacuated from the test site, sufficient medical facilities were available at the base camp for any emergencies that might arise. Three medical officers were brought down from Los Alamos, also for possible emergencies.

No therapeutic measures had been devised, and the measures listed were the only protective provisions set up against the effects of the blast. Speculations as to what they might be were rampant, but were of little help in preparing for possible eventualities.

ALAMOGORDO, N. MEX.

Detonation

The test of the atomic bomb was set for 15 July 1945 but was postponed for 24 hours because of unsuitable weather. The postponement raised to an even higher pitch the fatigue and tension in personnel at the base camp.

The bomb was fired at 0600 hours the following morning, 16 July, at a time when, Mr. Hubbard predicted, there would be a lull in, or a general collapse of, the wind pattern, followed by a general movement of winds to the northeast above 20,000 feet. His predictions were entirely correct.

The details of the detonation of the first atomic bomb are well known and need not be repeated here. The blast wave, as expected, produced an abrupt push, and, almost at once, a great creamy white cloud, tinged with magenta, formed and within 15 minutes rose to a height of about 70,000 feet. It then spread out in a mushroom effect, about 8 to 10 miles in diameter, and towered at this height, leaning slightly north and northwest, for more than 3 hours.

For a few seconds after the detonation, the light and heat were intense at the base camp 9 miles from the test site. During the first few minutes of cloud formation, large objects could be seen skyrocketing down from its lower third. About 3½ hours after the blast, the column could be seen to break up at different levels with the wind shear (a sharp discontinuity caused by two contiguous streams of air flowing in different directions). Small portions went in different directions at different levels, some to the west and southwest, and a few to the north. The main portion of the cloud, however,

particularly the part composing the mushroom above the 40,000- to 70,000-foot level moved, as predicted, to the northeast.

Fallout

By noon, 6 hours after the bomb had been detonated, the team appointed to survey its effect had identified a heavy fallout in a roughly oval area, extending about 10 miles north-northeast and including a slightly depressed crater covered with what seemed to be greenish glass. Fortunately, the fallout did not block any roads, especially the important east-west highway between Socorro and Carrizozo.

A few days later, fallout was found in some canyons north of this highway, about 30 miles away from the area of the crater. Some was also found at the base of the Chupadera Mesa, but the high cliffs and lack of roads prevented further exploration at this time, in addition to the fact that preparations had to be made for the departure of the survey team that had been ordered to leave for Japan on 13 August, to study the effects of the bombs that had been dropped on Hiroshima and Nagasaki.

When these observations were made, it was concluded, because the cloud and column had remained standing so long over the area in which the crater had formed, that most of the fallout had come down on the test site. It was not until almost a year later, when white-backed cattle were brought in from the uninhabited upper stretches of the Chupadera Mesa, that it was realized that fallout from 60 to 100 miles from the test site had been significant. The skip of 20 to 30 miles that occurred in the fallout pattern, about 20 to 30 miles from point zero, has been found, in subsequent U.S. tests, to be rather common. Apparently it is brought about by the choice of slow winds for the test period, with the aim of keeping the greater part of the fallout on the test site. The failure to detect this skip in the first test gave the false impression that the fallout had been restricted to the test area and also produced the impression that it was less dangerous than subsequent investigations proved it to be.

A much more detailed survey, made 5 years after the detonation of the bomb at Alamogordo by a team from the University of California at Los Angeles, showed that the fallout in the mountainous desert was much more widespread than had been suspected when the observations just described were made. Fortunately, intense radioactivity was never found at a significant biologic level in any cultivated or inhabited area surveyed. The potential hazard during wartime conditions was, however, very clear, even at this early date, to those who had participated in the investigation from the time the first bomb was tested.

JAPAN

Preparations for Dropping the Bomb

In anticipation of a successful outcome of the test detonation at Alamogordo, the atomic bombs fabricated at Los Alamos from material supplied

by Oak Ridge and Hanford to drop on Japan had been dispatched to Tinian in July on the U.S.S. *Indianapolis.* Captain Nolan went with them, to enforce safety precautions during their transportation from the United States and the loading of the planes on Tinian, which would be the takeoff point for the bombing of Japan.

Meantime, the Medical Section, MED, had been asked by the Air Force to investigate possible hazards to the crews of the planes that would drop the bombs on Japan. It was agreed that there were three chief hazards.

1. It was at first feared that the bright light of the blast might blind the pilot, so that he could not function. It was concluded, however, that the plane would be too far away from the site of the detonation for the intense light to affect him if simple precautions were taken.

2. The effects of heat and of gamma and neutron radiation were also feared at first, but they also were eliminated because of the factor of distance of the plane from the site of the drop.

3. Blast pressure was a more serious threat. It was known that a static pressure of 0.5 psi could break the wings off a plane and severely damage its flaps, but the situation in flight was dynamic, not static, and varied from minute to minute. No criteria existed to serve as guidelines. It was finally concluded that since the plane would be under emergency (that is, full) power after release of the bomb and, since it would be going in the same direction as the advancing blast wave, it would gain so much speed and distance that it would present the smallest possible surface to the advancing wave and thus would sustain the least possible damage in the conditions to be encountered. If information on static pressure could be taken as a guide, the estimated pressure per square inch at the time when the blast wave caught up with the plane would approach the danger level, but this was a chance that would have to be taken.

As events happened, the planes that dropped the bombs on Hiroshima and Nagasaki experienced severe, but not serious, bumps, and, because of their distance from the detonation, were not exposed to radiation.

Survey Team

An atomic bomb was dropped on Hiroshima on 6 August 1945, at 0815 hours. Seventy-six hours later, at noon on 9 August, a second bomb was dropped on Nagasaki.

On 11 August 1945, Colonel Warren received orders by phone from General Groves to organize a survey team to proceed by air to Guam, on the way to Japan, under special War Department orders (fig. 292), with three missions:

1. To take measures to insure the safety of troops that would occupy these atomic-bombed cities.

2. To investigate radioactivity on the ground and, if it were present, to record the amounts.

UNCLASSIFIED

"DECLASSIFIED - DOD Directive No. 5200.9, 27 September 1958"

1945 AUG 12 20:41

FROM...WARTAG AGO PERS DIV OFF BR ASGMT SEC AGPOA WASHINGTON DC 121925Z

TO.....CO AERIAL PE HAMILTON FLD CALIF

RESTRICTED / STAFFORD L WARREN COL ZERO FIVE THREE NINE FOUR ZERO ONE MC

LT COL HYMER L FRIEDELL ZERO THREE FOUR TWO FIVE SEVEN EIGHT MC

CAPT HARRY L BARNETT ZERO FIVE TWO FIVE ONE TWO MC

CAPT PAUL O HAGEMAN ZERO FIVE FOUR ONE EIGHT SEVEN THREE MC

CAPT NOLAND VARLEY ZERO THREE THREE EIGHT FIVE TWO TWO CE

CAPT HARRY O WHIPPLE ZERO FIVE SEVENTEEN TEN FIVE MC

CAPT WALTER C YOUNGS JR ZERO TWO FOUR SIX FOUR NINE FIVE MC

1ST LT JERRY H ALLEN JR ZERO SEVENTEEN THREE SEVEN NINE FOUR MC

FIRST LT B M BRUNDAGE ZERO FOUR FOUR SEVEN NINE TWO TWO MC

FIRST LT DONALD L COLLINS ZERO ONE ELEVEN THREE ONE FOUR EIGHT CE

FIRST LT GEOFFREY E GORING ZERO FOUR SIX EIGHT FOUR ONE TWO CE

FIRST LT JOE W HOWLAND ZERO FIVE FIVE SEVEN EIGHT TWO FIVE MC

FIRST LT RICHARD A TYBOUT ZERO FIVE TWO FOUR NINE TWO ONE CE

FIRST LT BERNARD S WOLF ZERO FIVE FOUR FIVE NINE SEVENTEEN MC

FIRST TECH SERV DET MISC WD GROUP WITH STATION SAN FRANCISCO CALIF

BY ORDER WARSEC WILL PROCEED BY SPECIAL PLANE FROM HAMILTON FIELD CALIF TO

GUAM MARIANAS FOR SIXTY DAYS TDY ON SPECIAL MISSION FOR CHIEF OF STAFF UPON

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FOUR TWO FIVE TRAVEL BY MILITARY OR COMMERCIAL AIRCARAFT DIRECTED PAR THREE TWO AR FIVE FIVE DASH ONE TWO ZERO CHANGES THIRTEEN AND NECESSARY FOR ACCOMPLISHMENT EMERGENCY WAR MISSION PD PROVISIONS AR THREE FIVE DASH FOUR EIGHT TWO ZERO C5 APPLY PD BAGGAGE ALLOWANCE SIXTY FIVE POUNDS AUTHORIZED PROCEED SUCH ADDITIONAL PLACES AS MAY BE NECESSARY PD WILL BE EQUIPPED ACCORDANCE COLUMN N WD PAMPHLET THREE EIGHT DASH SIX AS DESIRED INCLUDING PISTOL CALIBER FORTY FIVE PD PROVISIONS SEC TEN FOR PERTAINING MEDICAL REQUIREMENTS ARE WAIVED TEMPORARY APO FOUR TWO SIX ZERO SAN FRANCISCO

5506

A TRUE COPY:

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UNCLASSIFIED

WILLIAM L. HANNA
Major, M.I.S.

FIGURE 292.—Orders from Secretary of War creating the first technical service detachment ordered to Guam, to undertake a special mission for the Chief of Staff. These orders procured support and transportation into bomb-shattered Hiroshima and Nagasaki, Japan, before they were entered by military forces.

3. To report on the amount of blast and other damage caused by the bomb.

If Japan did not surrender unconditionally, the personnel of the survey team would be used as the nucleus of a tactical force to support the III and V Amphibious Corps in the later assault on that country. On the preceding day (10 August), however, the Japanese had agreed to accept the Potsdam ultimatum, though with certain reservations. The team left San Francisco on 14 August, though the formal terms of surrender were not signed until 2 September.

As soon as General Groves' orders to Colonel Warren were received, production plants and research laboratories were stripped of their portable Geiger counters, and enough ion chamber instruments, calibrating sources, and batteries were accumulated for a 2-month operation, since it was considered unlikely that any instruments or other supplies could reach the team later in time to be useful to it.

Colonel Warren, Colonel Friedell, and the other officers and enlisted technicians who constituted the survey team arrived at Tinian on 17 August. Here the group was split. Half went with Colonel Friedell to Zamboanga, Mindanao, with the III Amphibious Corps and, after many frustrating delays, reached Hiroshima on 26 September. They returned to Tokyo by train on 11 October.

The other half of the team went with Colonel Warren via Guam to Okinawa, to join the V Amphibious Corps. By this time, as just pointed out, all fighting in the Pacific had ended.

On 8 September 1945, Colonel Warren arrived in Hiroshima by air from Tokyo, in a party consisting also of Brig. Gen. (later Maj. Gen.) Thomas F. Farrell, CE, of the Manhattan Engineer District; Brig. Gen. James B. Newman, Jr.; Capt. James Nolan; Col. Peer de Silva; Col. Ashley W. Oughterson, MC, Consultant in Surgery, Headquarters, USAFWESPAC; Dr. Junod, of the Swiss Red Cross; and two Japanese medical officers, Adm. Masao Tsuzuki (*45*) and Maj. Matao Motohashi, who were to serve as interpreters. This party returned to Tokyo by train on 14 September, and 5 days later, with their technicians and equipment, they flew to Nagasaki (map 12), where they remained until 8 October (fig. 293).

Both Colonel Warren's and Colonel Friedell's groups left Japan by air on 12 October, in the Manhattan District plane *Green Hornet*, just ahead of the typhoons which struck those islands and Okinawa a few days later. The party reached the United States on 15 October 1945. The officers of the Medical Section at once prepared reports of their survey (figs. 294 and 295).

Japanese physicians and scientists were extremely helpful during the survey, and the general population, including those injured by the bomb, acted as patients act everywhere. There were no incidents, even though the survey party were in the bomb-shattered cities and elsewhere in Japan before the country was occupied by U.S. troops.

MAP 12.—Nagasaki, Kyushu, Japan, where second atomic bomb was dropped for military purposes. Note area of fallout.

It was the consensus of the U.S. survey team and of all the Japanese with whom its members came into contact that a coastal assault on Japan could not have been made without tremendous losses of ships and men, including U.S. casualties of perhaps 500,000, two to four times as many Japanese casualties, and complete destruction of Japan. The use of the atomic bomb, some observers held, gave the Japanese Government the opportunity to surrender without loss of face or need to commit hara-kiri. Fewer were killed by the bomb than had died in the Tokyo-Yokohama raids with conventional bombs. The ethics of the use of the atomic bomb had been raised by U.S. newspapermen in Tokyo, but many Japanese told the survey team they could not understand why the question should have been raised at all: Their own forces would have used it without the slightest qualm if they had had it themselves.

It is realized that this information was not the concern of the survey team, but the discussion came up when fixed coastal gun installations and Kamikaze stations were visited in the downwind area, and it is included for record.

FIGURE 293.—Survey team in driveway of tuberculosis hospital just before departure from Nagasaki in October 1945. Col. Stafford L. Warren, MC, chief of team, is holding doll and case given to the team by the Japanese medical commandant of this unit.

Radioactivity and Blast Damage

In spite of primitive transportation conditions and almost continuous rain, the instruments brought with them by the members of the survey team functioned satisfactorily and lasted well enough to permit an extensive survey of the detonation area in Nagasaki (map 13) and a somewhat less complete survey of the Hiroshima area, where team activities were hampered by lack of roads in the down (northwest) wind areas.

In all the areas examined, ground contamination with radioactive materials was found to be below the hazardous limit; when the readings were extrapolated back to zero hour, the levels were not considered to be of great significance. The explanation was that the detonation occurred at about 1,800 ft., and the fireball therefore did not actually touch the ground. Vaporized materials arose from the ground in the updraft and mixed with fissioned materials, but at that, the amount of radioactive contamination was lower than had been expected.

In Nagasaki, where the affected area was examined more thoroughly than in Hiroshima, the approximate center of the detonation (figs. 296 and 297) was indicated by a uniform charring of the top and sides of a single fencepost. Other posts in the same area (fig. 298) were more charred on one side

FIGURE 294.—Analyzing observations made in Hiroshima and Nagasaki, in office of Medical Section, Oak Ridge, Tenn., November 1945. A. Lt. Col. Hymer Friedell, MC, Col. Stafford L. Warren, MC, Capt. Charles Varley, CE, and Maj. James Young, CE, all members of the party that went to Japan immediately after the first atomic bombs were dropped. Note Atomic Bomb patch, which soon afterward became the official designation for military personnel of the Manhattan Project and Manhattan Engineer District. B. Lt. Col. Friedell trying out some Japanese medical record translation on Major Young, who is not convinced.

FIGURE 295.—Scene in outpatient clinic, Oak Ridge Hospital, 1 November 1945, with Col. Stafford L. Warren, MC (seated on table), reporting to hospital staff on survey of Hiroshima and Nagasaki. Listeners were medical officers of hospital staff, medical men from plants, a few dentists, and several nurses.

than on others. Trees, walls, and other standing objects leaned outward spokewise from this central point. The effect was particularly notable to the northeast, up the low hill on which the prison was located.

Induced radioactivity from neutron bombardment could be demonstrated in sulfur insulators, copper wires, and brass objects, in human and animal bones, and in the silver amalgam in human teeth, for a distance of about a thousand meters from the assumed mid point of the destroyed area. The neutron effects ceased rather sharply. It is unfortunate that it was not possible to make precise enough measurements to determine the full extent of the affected area.

The wind at the time of the Nagasaki detonation carried the debris to the east. It could be traced along the roads to the ocean for 90 to 100 miles in a path at least 40 miles wide at the seashore.

Nagasaki lies in the Urakami Valley, which is generally narrow but is about 2,500 meters wide at the detonation point. The eastern wall of the valley rises almost 2,000 feet above the valley floor. The hills were covered by terraces and rocks, and there were almost no dwellings to be damaged. In the next valley, however, the fallout path crossed the north end of the reservoir that supplied the city and also the houses to the north of it. The

remainder of the town south of the northern reservoir and some part of the lower Urakami Valley and the harbor area were virtually unaffected by contamination.

Blast effects were well marked for 2,000 meters north and south of the central detonation point in the Urakami Valley. Many peculiar concentration and skip effects were clearly evident, especially in a long series of steel frame buildings of the steel and torpedo works that ran north and south toward the harbor from the central area (figs. 299 and 300). Other stronger concrete and steel buildings had suffered obvious structural damage. Most concrete buildings had lost their steel window frames (figs. 301–303), which, it was evident, could become dangerous missiles inside the buildings.

In the Nagasaki Medical School, bodies were found entangled in the twisted window frames of the laboratory wing, which faced the blast. The contents of many rooms consisted of the wainscoting, the window frames, the ceiling, equipment, linens, and papers, which were all distributed over the floor (fig. 304) in a somewhat circular pattern. Many fuses had apparently been replaced with metal coins, and the fixtures hanging from the ceiling had therefore been violently twisted by the blast. The resulting short circuits had apparently lasted long enough to set the ceiling afire in many rooms, with the further result that the contents of the rooms burned along with the bodies of the staff. The prevailing wind carried the fire to the northeast part of the building, along the maple flooring and even up the maple treads of the staircase. The maple-floored ward areas on the upper floors were also burned but only downwind from the staircase.

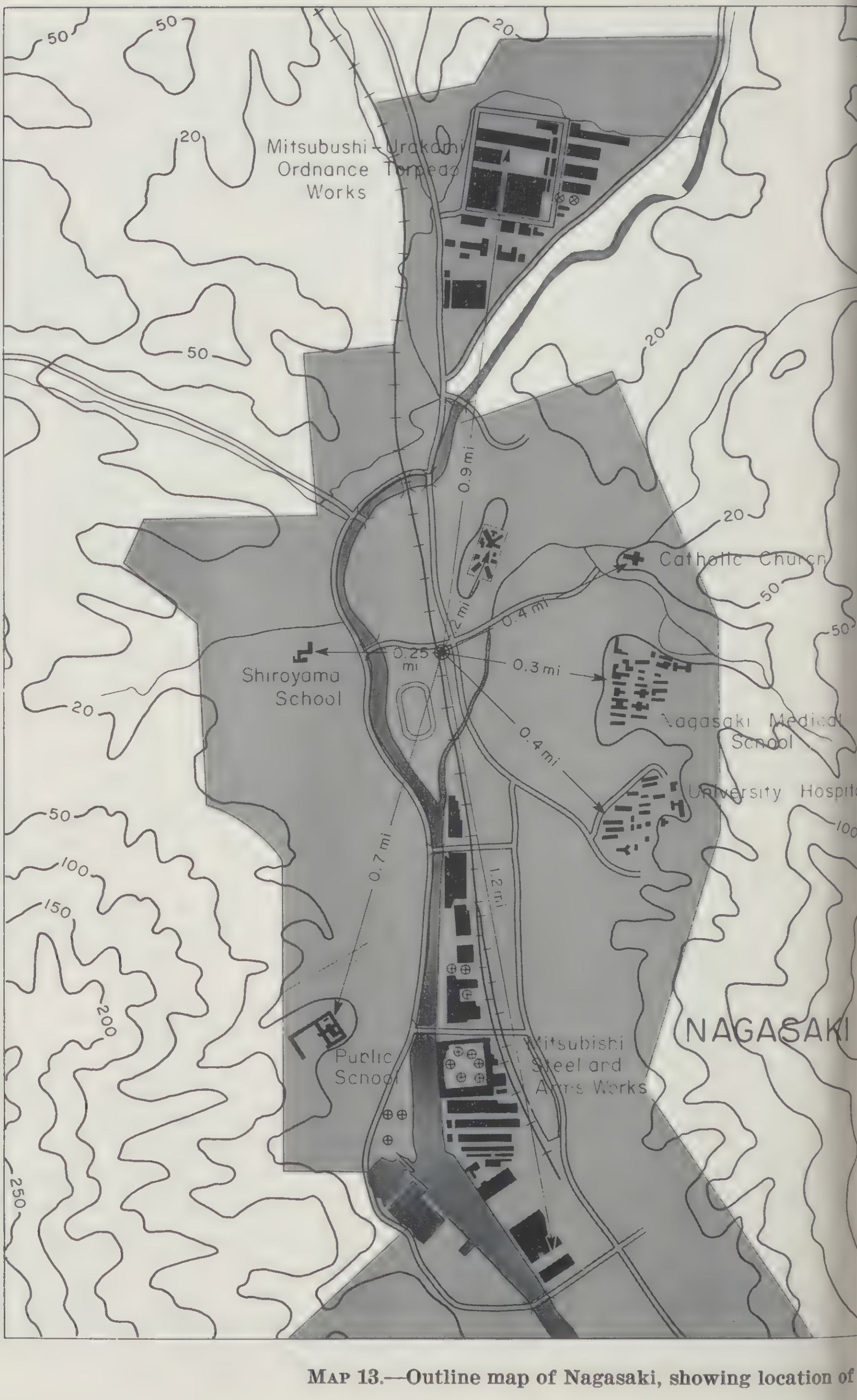
Many fires apparently occurred from similar short circuits. Overturned stoves caused many others. In both Hiroshima and Nagasaki there was considerable testimony to the effect that the fires started in multiple places at once but did not burn vigorously until about half an hour after the detonation.

The blast wave apparently put out the flames produced by infrared radiation in ripe brown wheat and smoldering wooden and dark surfaces before the fires from this source grew to any size.

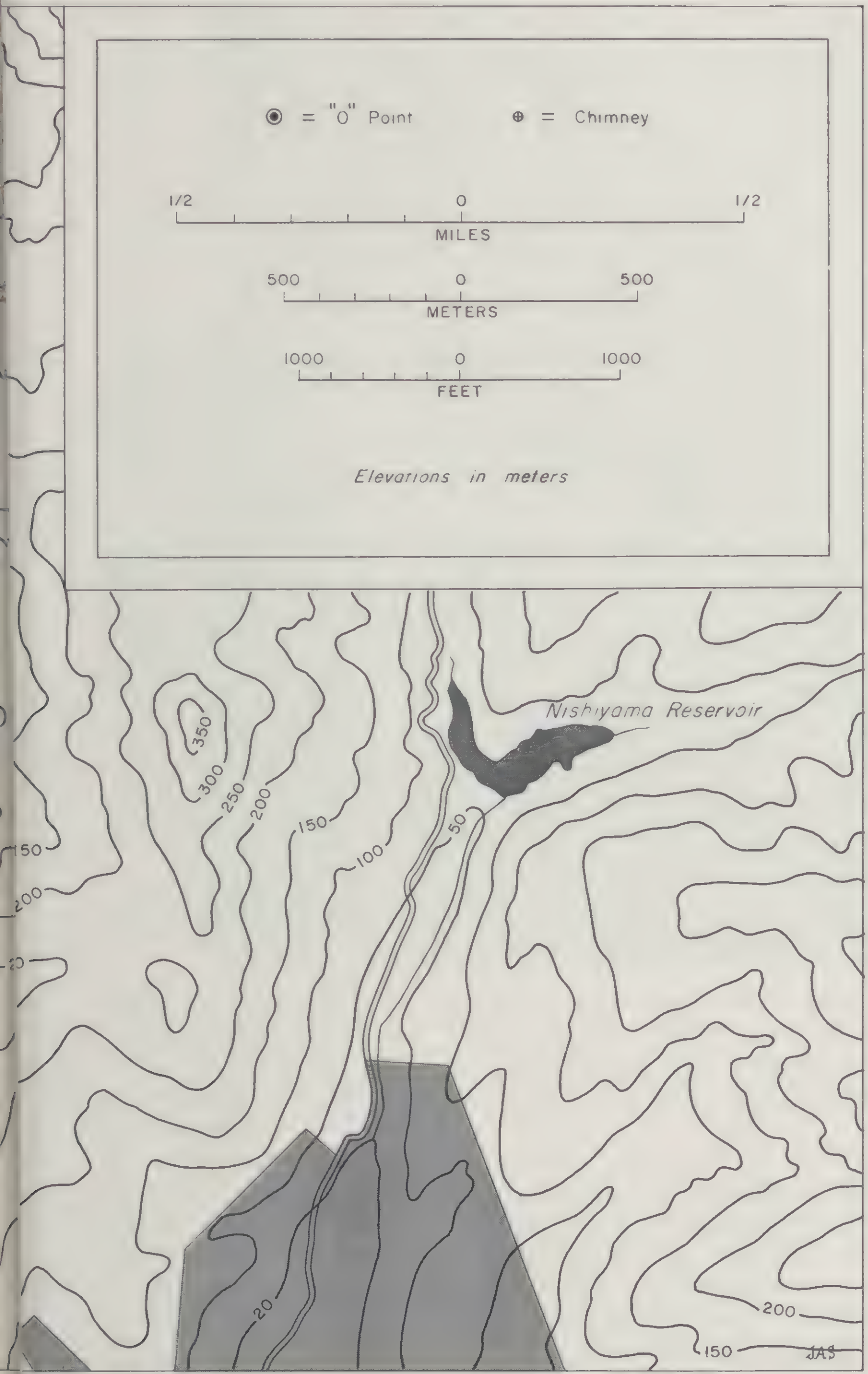
Clinical Considerations

When the survey team arrived in both Hiroshima and Nagasaki, it found feeble evidence of first aid efforts. Injured casualties lay wherever any sort of roof offered shelter from the elements. Mats were laid on the floor, and the Prefectorial Government in charge of the country delivered rice and tea to the patients. Helmets had apparently been used for carrying water to them. Later, some of the supposed patients were obviously malingerers, who had come to the aid stations for foods.

From their own observations and from testimony of Japanese, members of the survey team divided the morbidity and mortality of the atomic bombs that were dropped on Japan into the following phases:



Map 13.—Outline map of Nagasaki, showing location of



builings in which special casualty rate studies were made.

FIGURE 296.—Post and remnant of guard gate arm on railroad crossing directly under zero point at Nagasaki. Post is equally scorched on top and on all four sides, which shows that the heat came from above. Since the post was not consumed, it is evident that the fireball did not touch the ground.

1. Very large numbers of persons were crushed in their homes and in the buildings in which they were working. Their skeletons could be seen in the debris and ashes for almost 1,500 meters from the center of the blast, particularly in the downwind directions (figs. 305 and 306). The remains of large numbers of bodies were seen in poorly constructed trench shelters along the main roads. An occasional fresh body, with evidences of purpura, was found in ruined buildings. Collections of shoes (geta) were seen outside many of the first aid stations, where piles of human ashes were left from the extensive

FIGURE 297.—Two members of the Atomic Bomb Casualty Commission, Dr. John S. Lawrence and Dr. Herman E. Pearse, Jr., visit ground center of atomic bomb detonation. Hiroshima, Japan, June 1947.

cremations carried out in the first few weeks after the bombings; all bodies were cremated, at first, for military reasons, to conceal the number of dead, and later to clean up the area for sanitary reasons. Parties from the Japanese Army and the Prefectorial Government were still searching for bodies as late as 25 September.

2. Large numbers of the population walked for considerable distances after the detonation before they collapsed and died. Many who crowded on the trains that left both cities several hours after the blast died promptly, and their bodies were taken off at the first and second stops.

3. Large numbers developed vomiting and bloody and watery diarrhea (vomitus and bloody feces were found on the floor in many of the aid stations), associated with extreme weakness. They died in the first and second weeks after the bombs were dropped. These manifestations gave rise to fear of typhoid and dysentery, neither of which developed.

FIGURE 298.—Telephone post at considerable distance south of zero point, Nagasaki, charred on side toward detonation. The fire apparently continued to burn for some time after the blast. Note that radiation in this picture has come from the side rather than from above, as in figure 296. Intact pole is a postdetonation replacement.

4. During this same period deaths from internal injuries and from burns were common. Either the heat from the fires or infrared radiation from the detonations caused many burns, particularly on bare skin or under dark clothing (fig. 307).

5. After a lull without peak mortality from any special causes, deaths began to occur from purpura (figs. 308–310), which was often associated with epilation, anemia, and a yellowish coloration of the skin. The so-called bone marrow syndrome, manifested by a low white blood cell count and almost complete absence of the platelets necessary to prevent bleeding, was probably at its maximum between the fourth and sixth weeks after the bombs were dropped (that is, between 10 and 20 September). Most patients with purpura

FIGURE 299.—Airplane view of south portion of blast area in Nagasaki, showing Mitsubishi Steel and Arms Works and other buildings shown in map 13. Just north of crossroad are two collapsed pattern works shown in figure 300. Steel frame buildings, as shown in figure 301, were generally denuded of their corrugated iron covers by the blast.

died within a few days after it appeared, but some of them were observed in the aid stations by the survey team. Deaths from purpura occurred a few days earlier and stopped a few days earlier at Hiroshima than at Nagasaki, but otherwise the reactions in both cities were much the same in respect to both clinical manifestations and timing.

Epilation (fig. 311), anemia, and purpura were only occasionally seen in general surviving population, the assumption being that radiation sufficient to cause these pathologic changes was likely to be lethal. Nonetheless, an occasional patient with purpura, particularly if it developed late in September, seemed to have some power of recovery.

6. The death rate after 20 September was much lower than in the preceding weeks, though many casualties continued to die from protracted anemia, secondary infection, burns, and other complications.

As soon as patients with bone marrow and other injuries died in the aid stations, the spaces they had occupied were filled with patients and with severe

FIGURE 300.—Modern pattern works of German design at Nagasaki detonation of atomic bomb. The roof had collapsed upon about 300 workers in this building and in the similar building next to it.

burns who had survived and who were brought in by farmers and others of the local population, chiefly to take advantage of the rice and tea available there, as well as of occasional visits by physicians.

7. No count could be made of those who died outside of the devastated area, in public schools or other buildings to which they had been taken for care.

8. Occasional survivors (misses) in the devastated area showed little or no effects of radiation. Some of them had been in deep shelters or inside large buildings, but some escapes could not be explained.

9. The real mortality of the atomic bombs that were dropped on Japan will never be known. The Japanese had no accurate census at the time of the bombing. Afterward, no census was possible. Bodies were hastily cremated, as already mentioned. The destruction and overwhelming chaos made orderly counting impossible. It is not unlikely that the estimates of killed and wounded in Hiroshima (150,000) and Nagasaki (75,000) are overconservative.

FIGURE 301.—Interior of foundry building of Mitsubishi Steel and Arms Works shown in figure 299, about ¼ mile from zero point, showing chaos created by detonation, with torpedo molds and equipment thrown in all directions. Frame of building is grossly distorted, and its corrugated iron covering has disappeared.

Therapy

Occasional attempts to treat casualties showing bone marrow injuries with transfusions, plasma infusions, and penicillin were soon discontinued, chiefly because any needle puncture resulted in serosanguineous oozing that continued to death. Even pricks to obtain blood for blood counts caused oozing that could not be checked. It was thought that if the platelets were not too greatly reduced, because some functioning bone marrow was left, supportive treatment might be useful in carefully selected patients. If laboratory tests showed that the bone marrow was completely destroyed, the treatment available at the time the bombs were dropped on Japan was of no value at all.

OPERATION CROSSROADS

Planning and Implementation

The two bombs that were dropped on Japan in August of 1945 raised as many military and medicomilitary questions as they answered, and by the end

FIGURE 302.—Scene in Nagasaki 6 weeks after detonation, showing railroad bridge shifted by blast about 18 inches, enough to prevent trains sent out to pick up casualties from going further south. On the other side of the bridge is wreckage of streetcar which was apparently loaded with about 60 passengers. Across the valley, in the background, can be seen the crushed front of a building, empty at time of detonation. Note that all the window frames in front of the building are gone. Note also absence of ashes, indicating that there were no fires in this part of blasted area.

of the year it had become evident that the information needed concerning the tactical and other effects of such bombs on machines and men at war could be answered only by a series of tests under simulated war conditions (*46*, *47*).

The preliminary studies for these tests, which were known as Operation CROSSROADS, were conducted by the Joint Chiefs of Staff and led to the formation of a committee to investigate the project, with Brig. Gen. (later General) Curtis E. LeMay, AAF, as chairman. General Groves served as adviser to the committee. All the information collected in the Alamogordo test and in the Japanese bombings was carefully analyzed, and at General Groves' request, Colonel Warren, on several occasions, presented to the committee the observations he had made in Japan.

At the end of these deliberations, Vice Adm. (later Adm.) William H. P. Blandy, USN, was appointed to head JTF 1 (Joint Task Force One), which carried out Operation CROSSROADS on Bikini Atoll in the Pacific (fig.

FIGURE 303.—Interior of building shown in figure 302, with front wall displaced inward and window frames gone. There was no fire. Room has been cleaned by Japanese Army workers, but bench lathes exposed to weather are no longer usable. No information could be obtained on casualties among the workers who, if they were standing at workbench shown, were facing the blast.

312). Colonel Warren was assigned to the Task Force from the Medical Section, Manhattan Engineer District, to serve as radiologic safety adviser to Admiral Blandy and as Chief, RADSAFE (Radiologic Safety Section). On President Harry S. Truman's instructions to Admiral Blandy, Colonel Warren was to safeguard what was eventually a 42,000-man operation from the "peculiar hazards" of the atomic bomb and was to devise a radiologic defense organization and pattern for both military and civilian operations. At the end of the JTF 1 Operation, it could be said that no one had been injured by the "peculiar hazards" inherent in it.

Personnel.—The original RADSAFE group was made up of monitors and laboratory personnel capable of measuring radiation in air, water, and other materials. Experts in plotting, radio communication, and transportation were assigned later. During the 6 months of intensive planning and testing that followed the decision to conduct Operation CROSSROADS, cooperation among its components—the Armed Forces, university personnel, industrial contractors, and others—was almost ideal. Though each branch of the

FIGURE 304.—Urology clinic in medical school at Nagasaki 6 weeks after detonation of bomb, showing disarrangement of furniture and equipment. Ceiling soundproofing is torn off and scorched by fire that apparently started at base of ceiling fixture and was caused by violent oscillations of lamp and short circuit at its base. Fuses had been replaced by coins, and the short circuit ignited the cornhusk soundproofing which did not, however, burn sufficiently to drop embers on floor and start fires which occurred for this reason in other parts of the building. No bodies were found in this clinic.

Armed Forces had its special role in the operation, personnel were assigned for their technical skill alone.

Manpower was a major problem. The war was only just over, and the men needed for this operation, like all others who had been in service or participated in the war effort, did not care for the idea of spending 2 months or more on a tour of duty at sea or on a hot tropical island.

Eventually, however, the necessary personnel were secured. Monitors numbered 480, and the total RADSAFE force, with the crews of the monitor-

FIGURE 305.—View of Nagasaki 6 weeks after bombing, showing Roman Catholic Church that escaped heavy casualties because Mass had ended an hour earlier. Only parts of heavy brick walls still stand. Boxlike structure seen at bottom of hill to the left is the cupola. In far left is a school, whose upper story shows a slanting displacement. Building was used for industrial purposes at time of bombing, and no data could be secured concerning casualties among the work force. Shacks in foreground were constructed after bombing. Kindling in foreground is in an unburned area. The ground between this area and background is covered with ashes of houses, in which are skeletons consumed by fire within them.

ing boats and planes, numbered about 3,500. Capt. (later Maj.) Robert J. Buettner, MAC, who was assigned from the Medical Section, Manhattan Engineer District, to be executive officer (fig. 313), deserves great credit for his procurement of personnel and for other implementation of the plans.

A hard core of monitors and supervisors was trained on the U.S.S. *Haven* during the voyage to Bikini (map 14) which was reached on 12 June 1946. Almost all RADSAFE personnel were landsmen, and part of their onsite training was devoted to teaching them to get into and out of small taxi boats while they were loaded down with sensitive and very precious instruments.

Supplies.—Colonel Warren undertook to procure the necessary radiation detection instruments, film badges, metal foils, and other measuring devices (fig. 314), which at this time were made by only a few contractors and were in short supply. Geiger-Müller counting tubes, which were then made by hand in the laboratory at the University of Chicago and later by the Victoreen

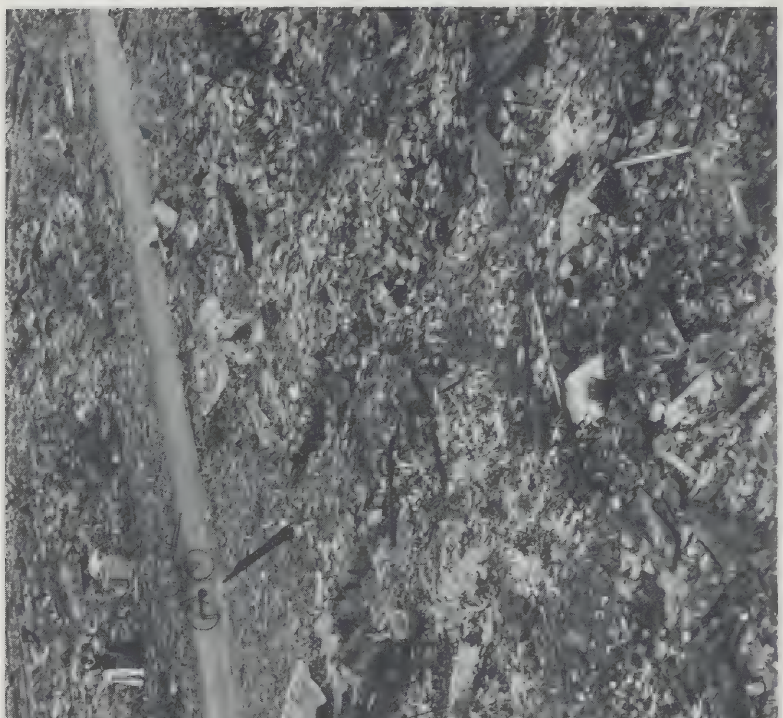


FIGURE 306.—Devastated area, facing west, in front of medical school at Nagasaki. Roadway has been cleared by Japanese Army and access to school buildings still standing is now possible. Shown in foreground are tiles and other remnants of burned buildings and houses in the area. Several large concrete bathtubs are visible. In immediate foreground are clusters of ashes and other remnants.

FIGURE 307.—Healed flash burn of back. This man, wearing khaki cotton clothing, was standing in the open, as shown in posed photograph. The blast threw him to the ground, and his cotton clothing was scorched and destroyed. His burns healed, and he recovered from mild radiation symptoms which he showed. This view shows scars of healed flash burns on back, elbows, and lateral aspect of right arm. The rest of the body was unhurt. Note huts in background, built for temporary housing after bomb was dropped. Note also, on horizon, trunks of trees denuded of branches by blast. Bushes and grass in ditch have begun to grow.

Instrument Co., had to be shipped weekly to Bikini during the second (BAKER, underwater) test in order to keep up with the repair rate. Some equipment was improvised (fig. 315).

Because of the large number of men RADSAFE would employ, a laboratory and headquarters ship was absolutely necessary if the target area were to be properly covered. The hospital ship, U.S.S. *Haven* was assigned for this purpose. It was refitted with special radiation laboratories and with instrument-calibration and electronic repair facilities. An 18-channel radio communication center was also installed.

Operating procedures.—The factual information required for the preparation of the operations manual, "Annex Easy," and the directions for the techniques of monitoring procedures were painstakingly written in Washington by Capt. George M. Lyon, MC, USN, who served as safety consultant and later as Chief, Bomb Safety Section. Colonel Warren, Colonel Friedell, and occasionally the medical consultants of the Manhattan Engineer District frequently conferred with him on the content of the manual.

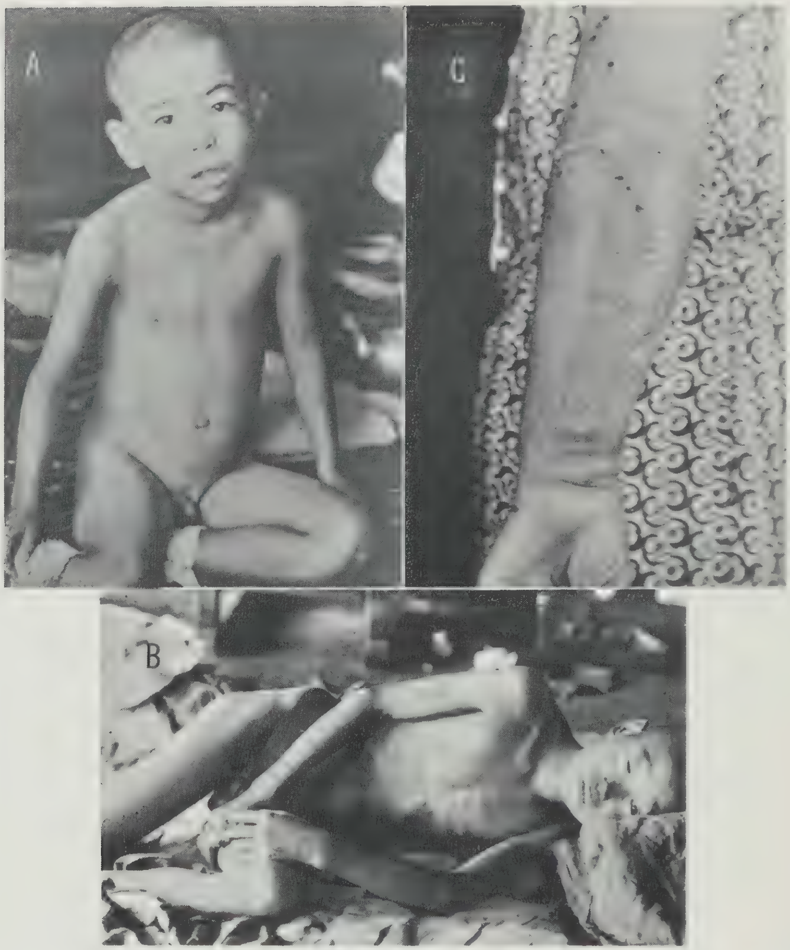


FIGURE 308.—Purpura hemorrhagica in Nagasaki after atomic bomb was detonated over city. A, B. Purpura hemorrhagica of moderate seversity. Both children show effects of bone marrow damage; child in view B is obviously in extremis. Hemorrhagic spots, while well distributed, are small and discrete. They show most prominently on arms in view A and on legs in view B. C. Forearm of Japanese woman with skin lesions and remnants of vesicles which did not become confluent. Note few small, discrete, black, hemorrhagic spots.

In the spring of 1946, all safety procedures were coordinated with the staff of JTF 1. President Truman had directed Admiral Blandy to "see that no one gets hurt," and it was the function of RADSAFE of the operation to be present at all Task Force activities and to stand guard with their Geiger counters to detect invisible dangers from radioactivity. The whole operation was enormously complex.

FIGURE 309.—Generalized petechiae in patient obviously near exitus, 6 weeks after bomb was dropped. This finding was associated with profound leukopenia and thrombocytopenia and was usually accompanied by other signs and symptoms of bone marrow damage. Note subcutaneous extravasation of blood and bleb caused by bleeding around needle puncture wound at elbow. The wound did not close by the normal clotting mechanism and sufficient serosanguineous fluid oozed from it to saturate the mat. Large numbers of casualties died in this manner during the fifth and sixth weeks.

Test ABLE

Test ABLE, which took place on 1 July 1946, was an airdrop of unspecified altitude. It sank several of the largely obsolete ships that composed the target field. The mushroom cloud formation, by now familiar to all, occurred as in all previous drops of an atomic bomb.

As soon as it was considered safe—about half an hour after the drop—

FIGURE 310.—Patient with extensive purpura and sordes 2 hours before exitus. Note extensive epilation of scalp, with eyebrows and eyelashes still intact. This man was picked up about 2,000 meters from center of detonation; the picture was taken on 3 September 1945.

monitoring planes flew over the target area to determine radioactive densities. Within 12 to 24 hours after the drop, most of the remaining ships of the target fleet were considered radiologically safe. Monitoring crews (fig. 316) were dispatched to the lagoon in groups of four fast taxi boats, each group under the control of an LCT, which communicated the water surface and hull radiation measurements by radio to the U.S.S. *Mt. McKinley*, the flagship of the fleet, as they were received from the crews. The measurements were plotted in a command post on the flagship. Water samples were collected at specified points and analyzed on the U.S.S. *Haven*.

Task Force personnel in tugs and larger vessels followed the first monitoring boats into the lagoon and boarded the target ships to obtain instruments that had been left on them and to assess the bomb damage. One or more monitors accompanied each boarding party and preceded it aboard, to make certain that there was no contamination or that radioactivity was low enough to be safe.

The film badges worn by all personnel were returned to the U.S.S. *Haven* every night, for development and measurement. Radiation exposures were measured and recorded for all personnel as individuals and as groups. Certain fixed badges, as well as metal foils, soap (because of its sodium content), and certain drugs (silver nitrate, arsenic, phosphates) in the ships' pharmacies were recovered from critical locations in the target ships. Those in close-in ships all showed radioactivity from the bombardment, and it was concluded that lethal doses would have been received by many of the ships'

companies, even in the heavier ships, such as the U.S.S. *Nevada*, if the ships had been close to the target area.

Test BAKER

Test ABLE was a shakedown for the monitoring operations of the second underwater test (Test BAKER), and many improvements in procedure were introduced in anticipation of the more severe contamination expected in it. Additional personnel were flown to Bikini before it. New measurements were planned, and additional equipment, including deep underwater Geiger counters, was secured. Dr. Dowdy, responsible investigator for the Manhattan Project contract at the University of Rochester, rendered great assistance in these matters, as he had for Test ABLE.

Test BAKER was carried out on 25 July 1946. Nine ships were sunk when the bomb was detonated under water, and the radioactive contamination of the ships not sunk was extreme and in many instances apparently permanent; it could not be removed by any means.

The immediate effect of the detonation was a lethal radioactive mist, about 3 miles wide even upwind, which developed under the great mushroom cloud of water and steam that formed immediately after the bomb exploded. This mist drifted north across the target area, crossed the reef between Bikini and Aomoen Islands (map 14), and then went out over the ocean, where the radioactive fallout was soon lost or dispersed by the vigorous action of the waves.

Radioactivity was so high on the surface of Bikini Lagoon that for some hours it was not possible to go into the target area beyond the periphery to examine the ships. Later attempts to wash the ships down were futile, even when detergents and alkalis were used. At first, tugs could not be brought alongside them for more than 20 minutes at a time. Later, when the ships could be boarded, the length of the stay on board had to be strictly limited. It was soon clear that many of the most contaminated ships would have to be sunk or be towed away to Kwajalein (largest of the Marshall Islands) or, later, to the west coast.

All the water in the lagoon remained highly contaminated, because of the presence of the highly contaminated water at the detonation site. Rope and rusty surfaces exposed to the water soon became highly contaminated also.

Clothing was quickly contaminated in the course of the investigations and was soon in short supply. Rusty radioactive water dripping off the superstructures of the contaminated ships left residual stains, even after the clothing had been laundered, and a good deal of it had to be confiscated because it could not be cleaned. Boots and shoes tracked contamination from the ships onto the tugs, and the footgear had to be discarded also. A change tug, to serve the purposes of the changehouses at Los Alamos and other laboratories (p. 865), improved the situation but did not entirely solve the problem.

FIGURE 311.—*See opposite page for legend.*

A wide variety of weapons and equipment used by the Army was exposed during Test BAKER, under the supervision of Maj. Gen. (later General) Anthony C. McAuliffe, Army Ground Forces. RADSAFE furnished monitoring services, especially in Test BAKER, in which many instruments and much of the equipment were in such highly contaminated areas that special monitoring and cleansing procedures were necessary before they could be recovered.

Marine and animal studies.—The details of the scientific data collected in Test BAKER cannot be related here, but special mention should be made of the comprehensive studies of the Marine Biologic Group under the direction of Prof. Lauren Donaldson of the School of Fisheries, University of Washington (p. 878), assisted by Arthur D. Welander, Ph. D., and Charles F. Pautzke, Ph. D. Their investigation of the radioactivity of all sorts in the lagoon, from plants, seaweed, corals, and shellfish (fig. 317) to herbivorous and carnivorous fishes, showed all of them to be contaminated to some extent. This was a most important finding, for it made all of these fishes unfit for food. It also introduced the possibility, if not the probability, of the spread of contamination as larger uncontaminated fish ate smaller contaminated fish in an endless cycle.

Termination of Operation CROSSROADS

The third test planned for Bikini, Test CHARLIE, which was to be a deep water detonation, was canceled in September 1946. Test BAKER had shown clearly that an underwater detonation of an atomic bomb would create lasting problems from the radioactive fission materials produced by it, not only because of the involvement of surface vessels but also because of the continued radioactivity in the crater area, which would continuously add to the radioactivity already present in the lagoon. The health problems, aside from the economic problems, which could be created by the detonation of an atomic bomb in a large harbor were beyond calculation or even imagining.

After Test CHARLIE was abandoned, Colonel Warren appointed a civilian committee (composed of Dr. Robert Newell, Dr. Robert Rodenbaugh,

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FIGURE 311.—Epilation in survivors of Nagasaki atomic bombing. A. Acute epilation, 1 month postexposure. B. Acute loss of scalp hair, with eyebrows and eyelashes intact. Note extensive purpura (30 August 1945). C. Almost complete loss of scalp hair. Note that eyebrows, mustache, beard, and hair on neck have not been affected. D. Almost complete epilation of top of head. Eyebrows and eyelashes intact. Purpuric lesions in skin of face and on upper lip. Hemorrhagic area in lower lip. Evidence suggests that this picture was made about 4 weeks postexposure. E. Epilation with very sparse regrowth of coarse hair. F. Slight amount of permanent epilation over upper part of scalp caused by X-ray radiation. Scalp above ears and neck was not protected by cap, and side of head, down to neckband of shirt, is badly scarred from infrared burns. Skin and cartilage of the ear escaped severe injury, which is unusual.

FIGURE 312.—News conference on U.S.S. *Appalachian* during Operation CROSSROADS, summer 1946. In foreground, Admiral Parsons, USN, Gen. William E. Kepner, USA, and Vice Adm. William H. P. Blandy, USN; at microphone, Col. Stafford L. Warren, MC; in background, Capt. George Lyon, MC, USN.

Dr. Failla, and Dr. Eugene P. Pendergrass) to determine which ships could be brought back to the mainland. In August, after the scientists had obtained their instruments and data from the target ships and Joint Task Force One began to prepare to leave Bikini, Admiral Blandy appointed Rear Adm. F. G. Farrington, USN, to select the ships to be saved or towed to Kwajalein and to arrange for sinking the rest. When most of the RADSAFE personnel departed in the U.S.S. *Haven*, Colonel Warren left Lt. David Bradley, MC, to monitor the vessels to be towed to Kwajalein.[6]

The remainder of the RADSAFE party returned to San Francisco in September, on the U.S.S. *Henrico*. During the voyage, Captain Lyon organized a Radiologic Safety School, which was the first such course ever

[6] Lieutenant Bradley's "No Place to Hide" is an extremely vivid account of the Bikini experience (48). The book makes very clear what an atomic bomb can do to ships, water, marine and animal life, and, by extension, to human beings.

FIGURE 313.—Col. Stafford L. Warren, MC, and Capt. Robert J. Buettner, MAC, in Radiologic Safety Section office, Operation CROSSROADS, summer 1946.

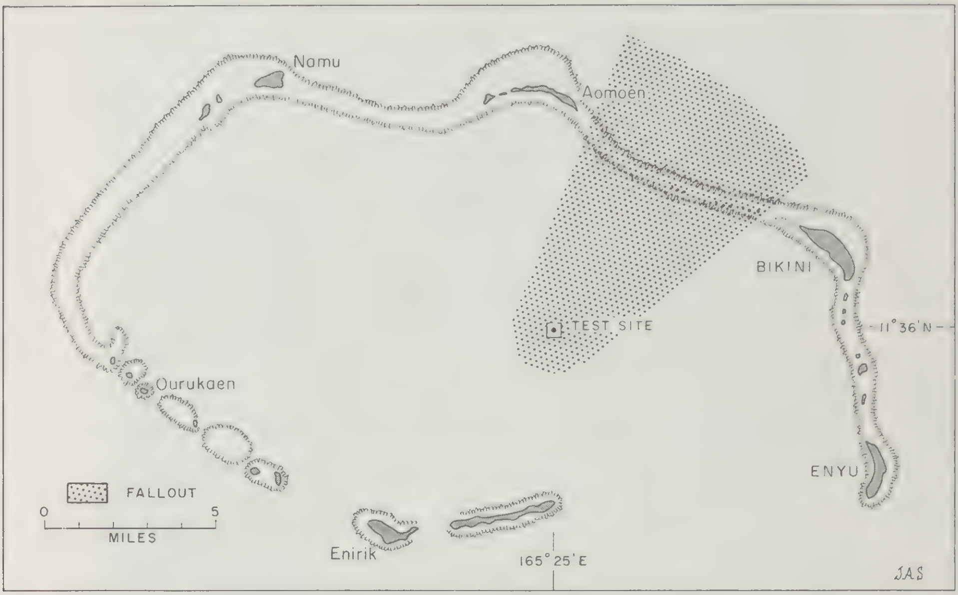
given and which served as the nucleus of a similar expanded (4-week) course later given in Washington.

When Colonel Warren was separated from service on 6 November 1946, after spending his time between that date and his arrival in San Francisco from Bikini on 7 September 1946, on the final details of the RADSAFE part of JTF 1, he became temporary civilian Chief of the Medical Division, Atomic Energy Commission. He served in this capacity until he was replaced by Dr. Shields Warren in February 1947.

CONCLUSIONS

At no time during the period between 1943 and 1946 were facilities allotted, or time provided, for the Medical Section of the Manhattan Engineer District to prepare a comprehensive history of its activities. The material in this chapter is a running account of the program, chiefly derived from memory and supplemented by only a few records. Regulations forbade notetaking. Official records were scanty. There were few charts and photographs. Many dedicated workers in both universities and industries which participated in the atomic bomb development have undoubtedly been omitted from this account because of the paucity of formal sources.

No one caught up in the excitement and drive of the Medical Section, Manhattan Engineer District, program could ever again be quite the same.



Map 14.—Bikini Atoll, from which Operation CROSSROADS was conducted. Note fallout pattern.

Other laboratory and industrial programs carried out during the war were perhaps similarly stimulating, but this program was of such a special nature that it left its permanent mark on those—and there were many—who were intensively involved in it.

Most of the medical and other personnel, including biologists, biophysicists, and health-safety personnel, who were engaged in this program have continued in the field of atomic science since the War. Many worked in the newly established Atomic Energy Commission. Many of those who returned to their former university positions or their former industrial environment have retained their interest in this new field and have worked on the application of the knowledge derived from it to education and further research.

The speculative imagination of the workers in this program was greatly stimulated by their wartime occupation. Few, however, at the end of the war could have conceived the real extent of the use of isotopes and of the allied knowledge in medicine, biology, and industry that has come about since the end of World War II. To those who had both the privilege and the responsibility of carrying out the tasks so briefly outlined in this chapter, it would seem that little imagination is required to accept the fact that nuclear weapons can be the ultimate destructive weapon for all mankind, and that the way to peace, unclear and difficult to attain though it be, must somehow be attained by the people of the world.

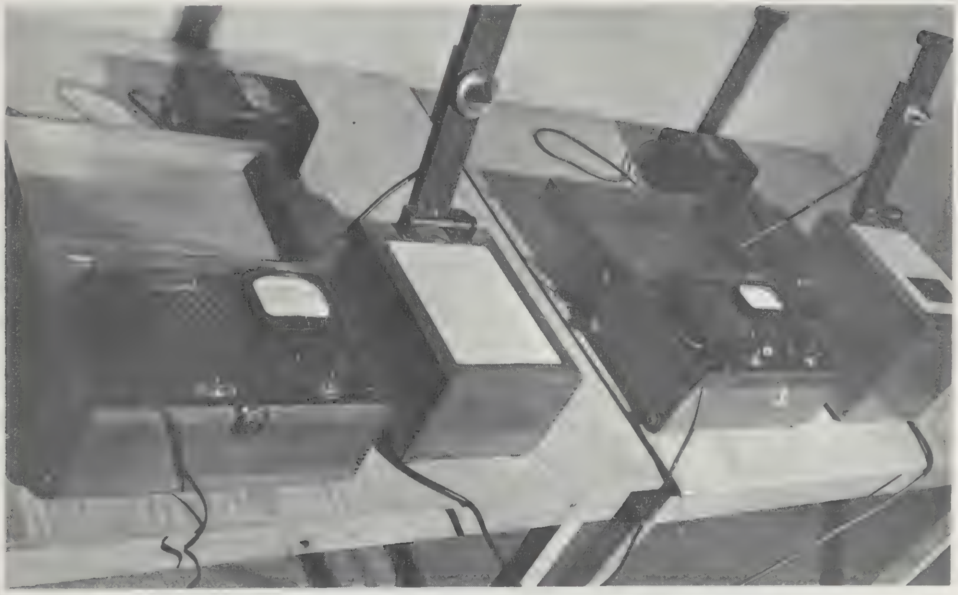


FIGURE 314.—Densitometers used by Photometry Division in Operation CROSSROADS.

FIGURE 315.—Personnel of Operation CROSSROADS, studying 3-dimensional model of radioactivity fallout pattern from surface to tropopause. This improvised, admittedly crude, piece of equipment, was really more efficient than more elaborate and more expensive items.

FIGURE 316.—Dispatching room, U.S.S. *Haven*, during Operation CROSSROADS, summer 1946. Equipment is being issued to monitoring personnel.

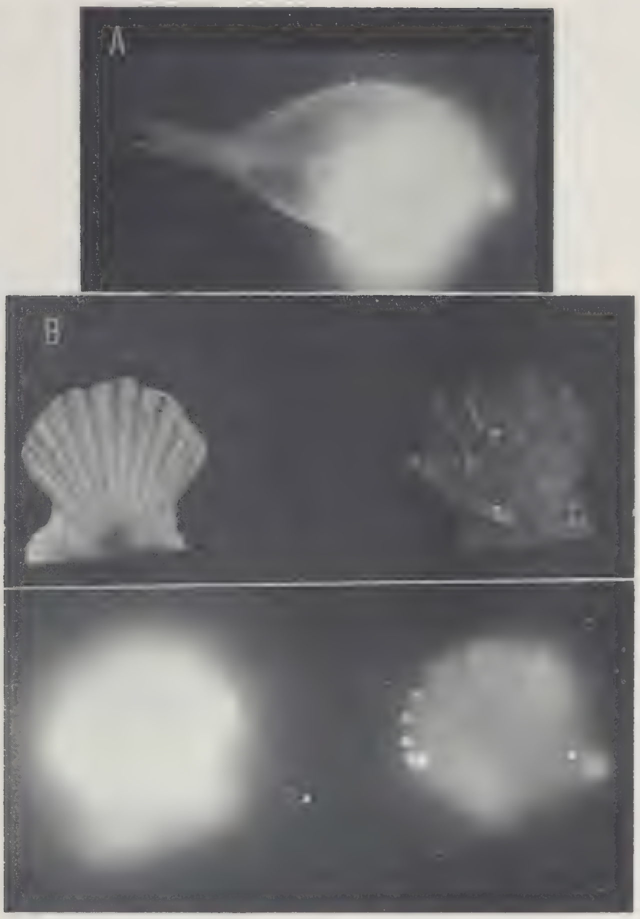


FIGURE 317.—Biologic materials collected from water of Bikini Lagoon after underwater (BAKER) detonation. All grasses, sponges, shells, shellfish, and other fish became radioactive at once and so remained, particularly in eastern or crater portion of lagoon. A. Autoradiograph of surgeonfish caught in lagoon after detonation of bomb. Digestive tract contains radioactive materials picked up in food. Vertebral column and bony orbit can be seen. B. Shells recovered by divers off hull of U.S.S. *Saratoga* on 29 July 1947, 1 year after Test BAKER. Each shell is extremely radioactive, as can be seen from its autoradiographic image (bottom). Radioactivity has slowly increased with passage of time.

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APPENDIX A

First and Third Weeks, Intensive Basic Course in Roentgenology for Medical Officers, Walter Reed General Hospital

Period	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
	FIRST WEEK					
8:00–9:00 a.m.	Outline of course plan (special problems).	Special problems.	Special problems.	Special problems.	Special problems.	Special problems.
9:00–10:00 a.m.	Roentgenology, roentgen physics, roentgenography, roentgen diagnosis, and roentgen therapy.	do	do	do	do	Do.
10:00–11:00 a.m.	Radium, radium physics, and radium therapy.	Rheostats, solenoids, choke, and coils.	Rectification: mechanical, thermionic, and inverse suppressors.	Mobile units.	Technical factors (ma., kvp, T. and D.).	Processing, and chemicals.
11:00–12:00 m.	Nature and origin of X-rays.	Transformer, step-up and step-down.	Detailed wiring diagrams.	Line requirements.	Physiology and treatment of electrical shock.	Film processing, and testings.
1:00–2:00 p.m.	The electron, static, chemical thermo, and piezo imbalances.	Auto-transformers, volt selectors, and line compensators.	Dissected stationary units.	Handling of controls, and stationary units.	Films, cardboard holders, and cassettes.	Examination.

APPENDIX A—Continued

Period	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
2:00–3:00 p.m.	Magnetism: terrestrial, natural, artificial, and electro.	Measuring instruments.	Handling of controls, mobile.	Stationary units.	Film handling, captioning, and filing.	Conferences, WRGH.
3:00–4:00 p.m.	Electric currents, units of electricity.	X-ray tubes, filament, and circuits.	Military courtesies, and customs of the service.	Facilities of post chaplain's duties.	Organization: Medical Service, and Surgical Service.	Do.
4:00–5:00 p.m.	Dynamos, and motors.	Simple wiring diagrams.	Mobile units.	Stationary units.	Darkroom construction features.	Do.
	THIRD WEEK					
8:00–10:00 a.m.	Special problems.	Special problems.	Special problems.	Special problems.	Special problems.	Special problems.
10:00–11:00 a.m.	Nonarthritic lesions of joints.	Spondylitis.	The skull: blastic lesions.	Fractures, and infections of paranasal sinuses.	Thoracic cage and pleurae.	Induction Board examinations.
11:00–12:00 m.	-----do-----	Tumors in and about the spine.	The skull: intracranial lesions.	Neoplasms of paranasal sinuses.	Mediastinum.	Photoroentgenology; cardiac configurations.
1:00–2:00 p.m.	-----do-----	Film interpretation.	Facial-maxillary conditions, general.	Film interpretation.	Lung fields.	Examination.

APPENDIX A—Continued

Period	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
2:00–3:00 p.m.	Film interpretation.	-----do-----	Facial-maxillary fractures and infections.	Fluoroscopy.	Heart: generalities.	Conferences, WRGH.
3:00–4:00 p.m.	-----do-----	The skull: general considerations.	Facial-maxillary neoplasms.	Radiation incurred during fluoroscopy.	Cardiac mensuration.	Do.
4:00–5:00 p.m.	The spine: development and anomalies.	The skull: lytic lesions	Paranasal sinuses and mastoids, general.	The thorax, general.	Heart: abnormalities of configuration.	Do.

APPENDIX B

First Week, Basic Course in X-Ray Techniques for Enlisted Men, Army School of Roentgenology, University of Tennessee

Period	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
8:00–8:50 a.m.	Introduction to course, its purpose and aims.	Function of the supply office.	The wave spectra.	Training films.	Demonstrations: d.c. and a.c. currents.	Function of personnel office.
9:00–9:50 a.m.	Registration and issue of texts.	Training films.	Energy and its transformation.	-----do-----	Resistance	Exam.
10:00–10:50 a.m.	Examination in basic arithmetic.	Radiology, its scope and application; responsibilities of X-ray technician.	Structure of the atom.	Refresher course in mathematics.	Refresher course in mathematics.	Do.
11:00–11:30 a.m.		Historical background of X-rays.	Electron theory.	Electrical units and terminology.	Demonstration: evidence of current flow.	Review and questions.
12:30–1:20 p.m.		Demonstration: production of X-rays in gas tubes; factors involved.	Elementary concept of electricity.		Ohm's law and power law for d.c. and noninducting a.c.	Inspection.
1:30–2:20 p.m.	Close order drill.	Demonstration: production of X-ray in modern tube; factors involved.	Magnetism	Close order drill.	Series and parallel circuits.	

APPENDIX B—Continued

Period	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
2:30–3:20 p.m.	Mass athletics.	Photographic, fluoroscopic, and electroscopic effects.	Fundamental units of electricity.	Mass athletics.	Electromagnetism.	Police.
3:30–4:20 p.m.		X-rays: nature, origin, and characteristics.	Electricity: static and dynamic.		Demonstration: electromagnetic induction.	

APPENDIX C

The following communication from Mr. E. R. Goldfield, of the Picker X-Ray Corp., was fortunately available when the preparation of this volume was undertaken, having been produced by him in response to the request for information on the prewar and wartime experience of his company. The communication has been somewhat shortened but otherwise is published essentially as it was prepared because it seemed to the Advisory Editorial Board for Radiology to represent an important aspect of wartime procurement that is not ordinarily recorded. In the opinion of the Board, the informality of the presentation added considerably to its value.

26 March 1956

PICKER MILITARY X-RAY EQUIPMENT PROJECTS

In 1935, it occurred to me that there might be both a military and civilian interest in a lightweight, shockproof head with a suitable tube stand, and within a year, such a device was developed. The military application was so strongly in mind that this device was developed in a manner that permitted changing X-ray tubes in the field without draining the transformer of its oil and without special tools or skill.

A folding tripod, especially lightweight, tube stand was developed to support this head and the necessary control. The unit had a capacity of 15 ma. at 80 kv. It was assembled in two packages and could be readily carried by one person. With tremendous enthusiasm, I made my way for the first time to the Army Medical School and there demonstrated this equipment to a Maj. W. W. McCaw and a Sgt. Lawrence F. Black. They were favorably impressed because the only military X-ray equipment that was available at this date was that which was left over from World War I. This consisted of the Waite and Bartlett Army bedside unit (covered in great detail in the first and second editions of the Army Manual, Hoeber Publishing Co.) and a table frame built during the first World War by the Kelly-Koett Co. This consisted of several long steel rails with quick attaching means to two cast aluminum legs. These in turn supported the litter. To this was attachable a tube stand.

In spite of the interest shown as the result of the demonstration, time went on and nothing happened. I then started to correspond, sometimes with Major McCaw and other times with our Washington representatives. Still nothing happened. Some years later, war clouds began to appear in Europe. Even the laymen could not help but believe that trouble of a serious nature was brewing. The middle of September, 1939, I was lamenting the lack of action in a conversation with Mr. James Picker. He urged that I discontinue writing and that I make a trip to the Army Medical School. I was by this time quite worked up, especially because through our foreign sales representative we had been asked by Belgium to develop a piece of military X-ray equipment. We had spent about a year experimenting. As a result of this work, we had come to the definite conclusion that the entire military X-ray installation was no stronger than the X-ray tube itself and its loss might leave an installation unworkable. We therefore considered it essential to find a means of eliminating one of the great hazards, insofar as the X-ray tube was concerned, that of prolonged fluoroscopy. After much experimental work, we came up with the idea that the most dependable method would be to find a means of prolonging the permissible operational cycle of an X-ray tube during fluoroscopy. We met with some success in our efforts and the unit that we had developed experimentally for the Belgian Army could be operated continuously at 3 ma. and 80 kv., but we were not satisfied for we felt that to be on the safe side it should be possible to operate at a minimum of 5 ma., 80 or 85 kv. continuously. All of this was

in mind at the time I visited the Army Medical School on 26 September 1939, where I met Capt. Alfred A. de Lorimier for the first time.

This visit started out with considerable disappointment but ended in a most encouraging way. The then Captain de Lorimier showed us some experimental models he had been working with. They were reconstructed World War I apparatus, and he was trying to find some way to reduce the weight and dimensions to make it possible to pack an X-ray table and an X-ray generator in one single Carlisle chest. I eventually learned that this decision of compactness had been arrived at by a Col. R. D. Harden. It was with considerable difficulty that I eventually located him just as he was leaving for lunch. I was invited to go along to the Army and Navy Club and during the course of the luncheon I was encouraged in the belief that, while it was most desirable to hold the weight and dimensions of the equipment to a minimum, still there would be some latitude depending upon the usefulness of the device. I reported this to Captain de Lorimier after lunch somewhat to his displeasure, but eventually he was most happy about it.

Prior to this visit, we had written to The Surgeon General offering on a no charge basis the facilities of our plant for any development work that we might be thought capable of performing. A similar offer was made to the Navy. These proposals were duly acknowledged.

During the afternoon of this first visit with Captain de Lorimier, he graciously took me to The Surgeon General's office to meet some of the men stationed there. This group included the then Maj. M. E. Griffin, Maj. S. B. Hays[1] and Lt. Col. F. C. Tyng. There we discussed the experimental unit that we had developed for Belgium. They were quite interested in the photographs and drawings. During the course of our conversation, I laid emphasis on the need of an X-ray tube designed so that it might run continuously at 5 ma. At this time, no tube was available with such a rating. Before our visit terminated, it was agreed that we should attempt to develop such a device. This is how the so-called Army Airflow tube was started. It was a worthwhile project. It tremendously increased the dependability of machines later in the field. It made use of a standard X-ray tube insert and increased rating brought about strictly by the method of cooling and protecting the insert.

I think everyone in the organization was thrilled by the fact that the ice had been broken and that there was a definite interest in the military X-ray program. As a matter of fact, Captain de Lorimier had prepared a specification but, before our day's conversation ended, this had been completely shot full of holes so we were not much further ahead than if there had not been one. Month after month, we proceeded to experiment. Model after model was developed. These models were sometimes sent to the Army Medical School but quite frequently Captain de Lorimier and Major Griffin came to Cleveland to view the latest model so as not to delay us by taking it away from us. We had in the meantime settled definitely on a unit of 30 ma. capacity. We had also settled on the use of a shockproof cable fed tube rather than a lower capacity self-contained shockproof head such as that demonstrated much earlier to Major McCaw. As a matter of fact, one of the things that spurred us on to develop a tube better able to dissipate heat was the fact that we had learned that there was some consideration of using two shockproof heads and of ultimately cooling them in a bucket of water. This seemed so impractical that it served to spur us on in the development of the X-ray tube.

It must be realized that by the time our experimental work started, war had broken out. We found ourselves under terrific pressure to push the development work as fast as possible, and yet, each time we developed a new model, someone found fault with it.

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[1] Later, Surgeon General of the Army.

If the miiltary authorities thought it was all right, we here at the factory were dissatisfied with it.

We finally felt that most of our problems had been solved and that we now had a suitable transformer, control, and X-ray tube, together with unique packing that was exceedingly light, strong, and yet provided a high degree of protection. Just at this moment, with never an inkling of this thought before, the Army Medical Corps decided this unit must be so designed that it could be supplied in either one of two ways. It must be possible to use less than all of the components and assemble it as a stationary unit consisting of a transformer, a control, and a tube designed for ready adaptation to the table unit now being designed by another X-ray manufacturer. Yet, it must also be possible to disassociate this equipment from the table and without tools convert it to a mobile bedside unit. Well, this decision threw the entire program into a tailspin. After several weeks' effort to try to convert it to such a design, it became evident that we had to start all over again.

Further complications were added to our problem at the plant by the fact that the Army Medical Corps actually wanted to get something into production as early as possible with the earliest possible delivery date, yet we could not learn the quantity that they might wish. They first spoke of 12 units. During the months of experimental work this figure advanced to 25, then to 50. With each new quantity we learned of, we attempted to start the production of parts and components that we felt quite certain would not be changed in this ever changing development program. At first we had 12 sets of parts, then 25, then 50, going through simultaneously with the experimental work. Needless to say, by this time all development work of civilian equipment had necessarily been stopped so that our full effort might be placed on the military program.

During the course of our experimental work, we became concerned about the possible failure of the terminals of X-ray tubes and transformers, knowing they would be subjected to high humidity. We developed a special terminal for military application. This was longer than was considered necessary for civilian use and had provision for oil or petroleum jelly sealing to reduce the tendency for moisture entrance. The problem of a continuously operating X-ray tube had by this time been solved and it was surprisingly simple. It made use of a small brushless motor-driven impeller within the oil of the shockproof X-ray tube, arranged to cause the oil within the enclosure to circulate. We provided a thermally operated switch which, upon slow but excessive heating and expansion of the oil, would shut off the X-ray exposure to protect the X-ray tube. The complete unit also included an external blower blowing a blast of air over the entire tube housing, but the feature of continuous operation had been achieved using standard X-ray tube inserts. Another safety device incorporated in it shut off the X-rays if current to either motor within the X-ray tube housing failed.

As you may recall during the early months, the war was referred to as a phony war but then Germany began to invade the low countries and they moved so fast that we began to wonder, had we done the right thing in advocating the design of equipment as powerful and as versatile as that which was being developed, or would we have been further ahead to have gone along with the idea that the entire unit had to go into a single Carlisle chest. One could not help but wonder if the time might not come when the only means of transport would be by way of aircraft. I guess for the time being, we kept such thoughts to ourselves for we were approaching the completion of the development work. We had devised every conceivable type of test that we could think of but we were fearful of the responsibility of being the only one who had tested the equipment that might prove to be so vital. We offered to build three machines for free that might be loaned to England to have them tested in the field. It must be realized that at this time the Medical Division did not have the test facilities that would be desired.

When the equipment was accepted, as can be expected, they wanted them overnight. The first contract was for 110 units. Packed with each was a questionnaire by means of

which we tried to determine what further improvements could be made, what faults occurred in the field, and what we could do to make better units. Because we were the only ones who had tested the equipment as severely as we thought it should be, we proposed to guarantee the first 110 machines, except for the X-ray tube and cables, for a period of one year, and we offered to take them back and completely modernize them at the end of a year, bringing them up-to-date with any improvements that might be made during that period of time. This offer was eventually gratefully accepted and 85 of the units were located and returned on a gradual basis for modernization. The best proof of any device is actual field usage and it was also true in this case.

We became concerned about the possibility of water getting into the packing. We built a lawn type sprinkler system up on the roof of the building where we could put packages and showered them day and night. We eventually developed a simple expedient of a large wax impregnated canvas bag. Each package containing a given list of components was installed in such a bag with the excess material of the bag simply rolled and folded so that it could always be reused. This protection was applied before crating and served as an ideal means of keeping water out even when units were submerged. Unfortunately large quantities of units had been produced before this improvement was made. Later in this article, a story will be repeated that had to do with the submersion of such equipment even before the protective covering was devised.

You will recall that early in the war a materials priority system was set up. This was intended primarily to save critically needed materials from going into civilian applications that might possibly be avoided so that these materials would be available for critical war application. Practically all components of X-ray machines became increasingly difficult to obtain, and of course compliance with the priority system was the first order of business. This meant that one would have to have a contract and contract numbers in order to secure the material for production. The Army Medical Corps labored under severe handicaps during the war. In other words, it was comparatively easy to obtain the material to make a gun but it was exceedingly difficult to obtain the material that might contribute to the saving of human life. This provided us with one of its most vexing problems. Theoretically, it would be impossible to obtain material for production without priority numbers. Actually we proved that it could be done for, with contract after contract, we learned how to start production before the contract was received. The officials in Washington would plead: "Produce them without contract number; you will eventually get the contract but we must have the equipment without delay."

The Government was very anxious to prevent the priority system from breaking down; therefore, inspectors called and investigated the purchases and commitments of a manufacturer at regular intervals. In other words, one branch of Government was sending out men to tell us that we could not continue to obtain material without priority numbers, and therefore contract numbers. The Army Medical Corps, on the other hand, was pleading for the early production and delivery of everything they required. This produced many heartaches. The Medical Corps won out. Every contract was produced before the date deadline and I am glad to report the priority division never put any of us in jail. More than 10,000 units were produced.

This problem can best be appreciated if you realize that the military X-ray program was being stepped up continually. The frequency of letting contracts and the size of each contract was constantly increased. Due to the fact that it was impossible to learn anything about the eventual quantity requirements at the outset, we had made a modest investment in tools and production facilities. It was soon apparent that we would not be able to meet the required shipment schedules unless these facilities were improved. It was impossible to obtain more floor space at the plant. The development program on military equipment was slowing down and the engineers were transferred to one project after another concerned with the design of automatic or semiautomatic facilities for the manufacture and testing of parts and components. The entire machine was retooled.

Over the years, the program continued to accelerate to such extent that it was retooled for the third time. The amount of civilian production was limited by governmental decree so that by far the greatest part of our effort was on the military equipment. The number of employees that could be added to the payroll was limited by the floor space available. The setup in program and reduction in costs had to come about through new and ingenious methods of production. The volume became so great that there was no room to pack the day's production. This then was done in the regular aisles of the plant after closing time by a special crew who loaded each day's production in freight cars waiting at the plant door.

We were still very much concerned with the fact that, at our first day's meeting with Captain de Lorimier on 26 September 1939, they were hopeful of getting an entire X-ray machine in one Carlisle chest and, by now, an X-ray installation included a table, a generator, a darkroom, a gasoline generator, a heated or cooled developing tank, and many other items—a small truck load. We inquired if it might not be wise for us to develop a second, less versatile, less powerful piece of equipment to be used in more advanced positions. We were told by all means to forget it, but, for some reason or other, we simply could not get this idea out of our minds. So, as a sideline, without interference with the military production, we started to develop a smaller, lighter unit. Model after model was produced. We sent photographs of the different models to the military authorities but they were never interested. On their visits to the factory, we did show them what we were doing. They still thought we were wasting our time and money but I guess in war one can never tell the turn of events that may follow. Eventually, more than a year later, they wanted this unit in production overnight. This was eventually accomplished and it became known as the Air Corps Unit—more reference to this a little later on.

Earlier, I referred to the development of a so-called Air Corps Unit. The object was to provide the smallest lightest table and generating unit possible, packed so as to facilitate transportation by aircraft. As I stated, we received a call from Washington, inquiring if we were still playing with the idea and would it be possible for Colonel Griffin, Colonel Ledfors, and Major de Lorimier to see it in Cleveland the next morning. We stated it would be impossible, that the last model had been completely dismantled and the parts were undergoing changes or replacement in order to provide an improved model. There was considerable difference of opinion as to when it should be made available for inspection, but they won as usual and within a week they were in Cleveland examining it. They were very happy that we had insisted upon continuing on this project. The design was not complete, and of course there were no tools for production. However, they insisted upon an almost immediate delivery of a quantity. Four were turned out in 10 days; 12 more within 30 days. This unit had a capacity of 15 ma. at 80 kv. and provided an over the table tube stand or an undertable fluoroscopic tube with provisions for limited vertical fluoroscopy and with full foreign body localization. Before the war came to its end, 1,500 had been produced.

I referred to the production of equipment without priorities, but, to elaborate on it a little further, here were the problems that we were faced with. At times, we had outstanding commitments for the purchase of material as high as $2 million. We had no contract numbers to support such purchases. We had no letter of intent to purchase. We had nothing but a letter or, as a rule, a phone call from Washington explaining the necessity of the earliest possible delivery. As I look back on it, it was a terrible, almost unforgivable risk to run to have made such purchase commitments. On the other hand, there was the feeling of absolute confidence in everyone that we were associated with in the military program and the belief that they shared in their minds and hearts the risks that we would take. It all worked out OK in the end. Nothing ever happened to affect our confidence in them. As a matter of fact, speaking for myself, it was a wonderful experience to work with the officers that we were privileged to work with. Their word was always as good as a bond, appreciation knew no limits for the

effort that we would make, and we had the feeling that we were trusted with the same limitless degree with which we trusted them.

This treatment probably had much to do with the desire on our part to save every penny we possibly could in the production of the equipment and to pass it back on to the Procurement Department. At any rate, the price of practically every bid was reduced in comparison to the one before it. The increasing volume and experience, and the fact that we were unable to employ more people but had to find various tricks and shortcuts which resulted in laborsaving, helped bring the price down. At any rate, the price dropped to less than one-half between the first contract and the last.

Before we had accomplished very much in the production program, we realized that this equipment would require intelligent service in the field. We tried to cover as much of it as we possibly could in a rather unusual instructional manual. We went further by designing the equipment so that within the equipment itself, and not stored in packing cases, were a few simple tools and a group of spare parts as well as the instruction manual, so that the users might perform some of the service operations that might be required.

Some of the radiologists by now in various fields of operation were old acquaintances of ours. Many were men we did not know but a great many of them turned to us when they were in trouble. There was by necessity much red tape to go through, especially in the early days, in any effort the men in the field might make to obtain much needed spare parts. So we had frequent requests from overseas directly from the men involved, begging and pleading for a few small items that it would be permissible for us to send, for you will recall that one could send overseas, packages up to 5 pounds in weight with certain dimensions. We took advantage of this opportunity to send, no charge, highly prized packages of spare parts. The total value of all that was sent was quite insignificant compared to the help it rendered.

We also realized in the early days of our effort that something had to be done to train men. We volunteered to train any young men they cared to send to the plant in the service and repair of X-ray equipment. Now it must be recalled that the Medical Corps of the Armed Forces was also purchasing standard civilian X-ray equipment at the same time that they were purchasing specially designed military equipment. By the time we had trained a dozen or so men here at the plant, we became conscious of the fact that this plan left much to be desired because it did not give these young men an opportunity to become trained in each of the competitive lines of equipment, civilian in nature, which they might encounter in their work. As a result of this, we started a campaign to try to have established a school to be operated by the Medical Corps. We offered to supply two instructors and we believed that our competitors would be willing to do something similar, with each of us to supply the school with whatever models of equipment were necessary for the instruction of the class. Such a plan was eventually adopted and such a school was set up in St. Louis under Col. R. K. Stacey. This school location also made possible something else that we frequently had called to our attention, which we may or may not have been instrumental in its creation, and that was a government owned laboratory that could determine whether or not a piece of equipment met the specifications, and the place where a piece of equipment could really be put through its paces to determine its overall quality. We did supply two instructors for this school. One of them was Maj. John Russel who prepared the service instructions on all of the equipment. A great many young men benefited by the X-ray instruction course that was conducted there under Maj. Dallett B. O'Neill who had many years of experience teaching at the University of Pennsylvania.

Some excellent manuals were prepared during the war that anyone interested in this subject might care to read. They touched on all items pertaining to X-ray that were used during the war. All three were published by the War Department and they are:

Technical Manual 8–633—X-ray Field Unit Fluoroscopic Foreign Body Localization, complete item No. 9621500.

Technical Manual 8–632—X-ray Field Unit Machine Chassis and Table, items Nos. 9608508, 9608510, 9609005, 9609010, and 9614500.

Technical Manual 8–280—Military Roentgenology. To these might be added the instruction manual included with the equipment entitled, "Army Field Unit Equipment, Item No. 96215 and U.S. Army X-ray Field Equipment, Item No. 96085, Item No. 96090."

I would like to take this opportunity to list the names of many of the officers whom we worked with throughout the war production program. Inadvertently I suppose a few might be omitted but, because I have mentioned the excellent relations between them and ourselves, I feel that their names do have a place in these recollections:

Maj. Gen. James C. Magee	Col. Stuart G. Smith
Col. Martin E. Griffin	Col. Gustave E. Ledfors
Col. Alfred A. de Lorimier	Col. John A. Worrell
Col. Charles F. Shook	Lt. Col. H. S. Currie
Col. R. D. Harden	Lt. Col. Burwell B. Smythe
Col. Royal K. Stacey	Lt. Col. H. T. Marshall
Col. Francis C. Tyng	Maj. William Herzog
Lt. Col. Silas B. Hays	Maj. Hal D. Oakley
Lt. Col. Charles G. Gruber	Maj. Dallett B. O'Neill
	Capt. F. L. Mahady

I should like to conclude this story of the wartime development and production of X-ray equipment for military use with the citation of a letter written to me after the war by Colonel Shook, one of the medical officers with whom I was associated during the war:

4801 Connecticut Ave., N.W.
Washington 8, D.C.

Dear Mr. Goldfield:

The folowing story was written in the spring of 1944 in compliance with a request from the War Department to submit evidences of equipment or supplies exceeding expectation. I have never learned whether this event was ever publicized or not. If not, it should have been, for it was conclusive evidence that industries involved in the manufacture of medical and surgical supplies and equipment had not sacrificed quality for quantity.

This tale was told to me personally by Colonel Harrison, the commanding officer of the 35th Station Hospital. The hospital had been operating in a seaport town of northern Algeria when it was ordered closed and moved to Corsica. The movement was accomplished but not without some difficulty.

One of your field units after being carefully crated for movement was unfortunately riding upon a truck which left the road and rolled over a 20-foot embankment. This was while enroute to the ship for transfer to Corsica. The truck and cargo were retrieved without further delay. Upon reaching Corsica, it was found that the ship could not land because of damage to the harbor and the property of the hospital had to be lightered in. The small lighter upon which the particular unit was riding saw fit to run into a small mine and promptly sank in about 20 feet of water.

It was 10 days before the X-ray machine was salvaged and turned over to the hospital. When it arrived, it must have looked like something the cat left but the personnel went to work, drying and cleaning and when they were through, they threw the switch and the machine worked beautifully. This was truly a miracle as it would have taken days to get a replacement machine up from Africa and the opening of the hospital would have been hindered.

I could enumerate many other stories of how medical and surgical supplies and equipment withstood the ravages of war, weather, usage and transportation but I think

it is all summed up in my aforementioned statement which I have repeatedly given to the many industrial groups responsible for such credible results. At no time was there any evidence that the manufacturers of medical and surgical supplies and equipment sacrificed quality for quantity. Furthermore, no American soldier suffered for lack of a critical piece of supply or equipment either in the Mediterranean or European theaters. You know what positions I held and that if such a lack had existed I would surely have heard of it.

Kindly extend my personal thanks to the staff and employees of your plant who made the above possible.

Sincerely,
C. F. Shook
Colonel, MC.

Friday, 28 August 1942, was a proud and happy day for Messrs. James and Harvey Picker, the company executives, and the men and women of the Picker X-ray Corp., for on this day the first Army-Navy "E" Award in the X-ray industry was made to the company. The pennant was presented by The Surgeon General, Maj. Gen. James C. Magee. A great many of the officers, whose names are listed above, were present for the occasion. It was quite a family reunion. Judge Stanley Orr was master of ceremonies. The mayor of the city of Cleveland, Frank J. Lausche, was one of the speakers. The last Navy nurse to escape from Corregidor was present, Ens. Ann Bernatitus. Accompanying her was Lt. Helen L. Summers, Army nurse. Appropriate tribute was paid to the employees.

E. R. Goldfield.

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[1] Unless otherwise specified, all entries refer to radiology and to World War II.

The following code of standard abbreviations has been used: CBI (China-Burma-India Theater); CPA (Central Pacific Area); ETOUSA (European Theater of Operations, U.S. Army); MED (Manhattan Engineer District); Met Lab (Metallurgical Laboratory, University of Chicago); MTOUSA (Mediterranean Theater of Operations, U.S. Army); NRC (National Research Council); NATOUSA (North African Theater of Operations, U.S. Army); OTSG (Office of The Surgeon General); POA (Pacific Ocean Areas); SPA (South Pacific Area); SWPA (Southwest Pacific Area); VA (Veterans' Administration); and ZI (Zone of Interior).

☆ U.S. GOVERNMENT PRINTING OFFICE: 1966—O 780-336

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